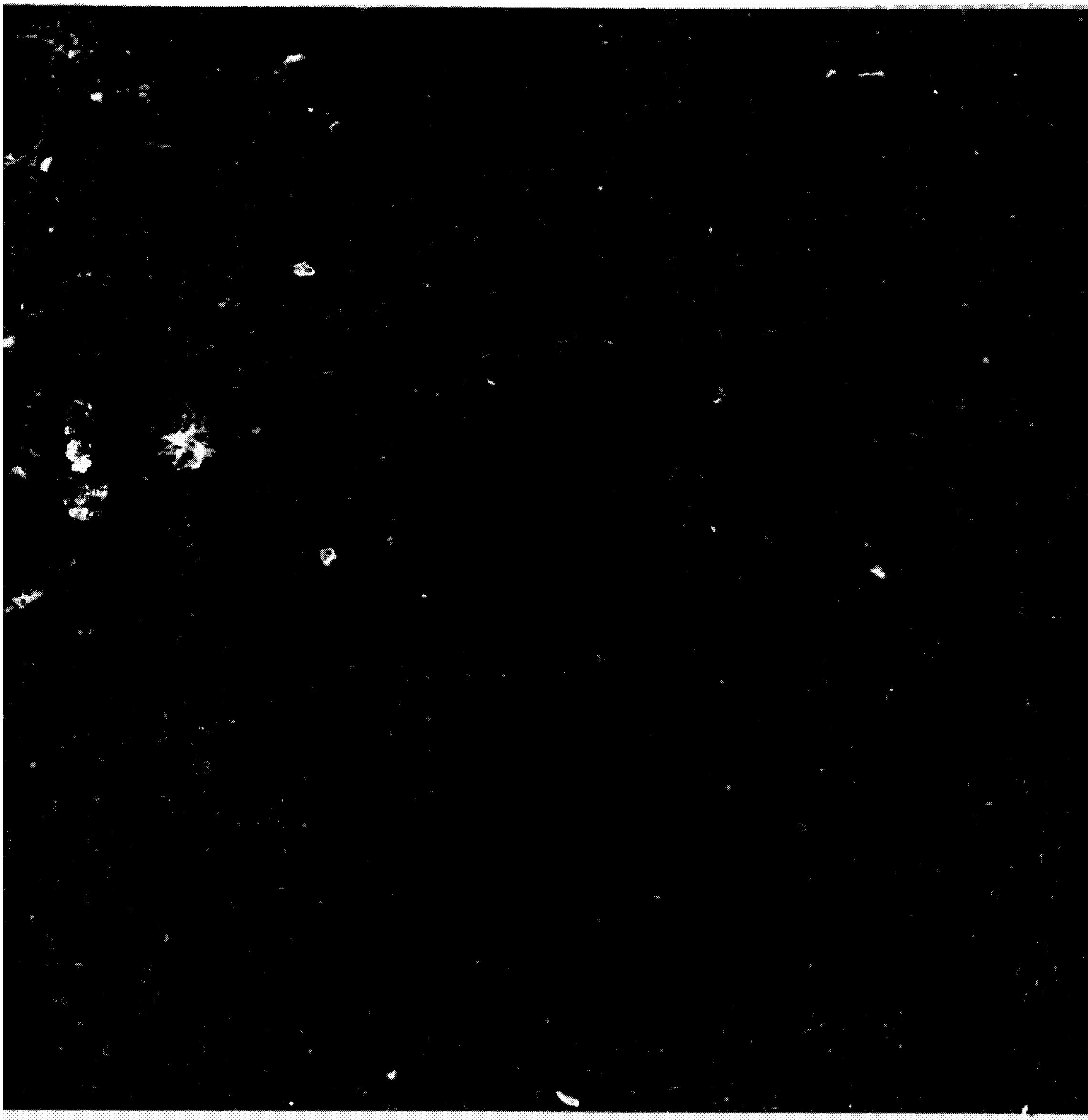

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Volume II

TECHNICAL REPORT

CONCEPTUAL DESIGN STUDY OF A SCIENCE AND APPLICATIONS SPACE PLATFORM (SASP)

OCTOBER 1980

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PREPARED BY: Fritz C. Runge
Study Manager
McDonnell Douglas Astronautics Company

APPROVED BY: Max Nein
COR
NASA/Marshall Space Flight Center

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH
5301 Bolsa Avenue Huntington Beach, California 92647 (714) 896-3311

PREFACE

This document (Volume II, Technical Report) contains material prepared by McDonnell Douglas Astronautics Company on the Conceptual Design Study of a Science and Applications Space Platform (SASP); as defined in the Statement of Work for Contract NAS8-33592 by Marshall Space Flight Center, where the contact is:

Max Nein, COR
NASA/Marshall Space Flight Center
PS02, Building 4200
Marshall Space Flight Center, AL 35812
Telephone: (205) 453-3430

Requests for further information will be welcomed by the following McDonnell Douglas personnel:

- Fritz C. Runge, Study Manager
  McDonnell Douglas Astronautics Company
  5301 Bolsa Avenue
  Huntington Beach A 92647
  Telephone: (714, 896-3275

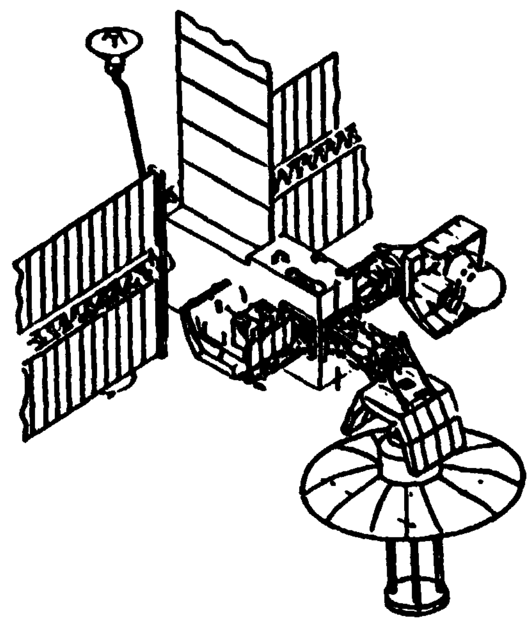
- Vince W. Madigan, Contract Administrator
  McDonnell Douglas Astronautics Company
  5301 Bolsa Avenue
  Huntington Beach, CA 92647
  Telephone: (714) 896-2201

- Roger D. Nichols, Field Office Representative
  3322 Memorial Parkway So.
  Suite 122
  Huntsville, AL 35801
  Telephone: (205) 881-0611

NOTE: Volumes I and III are Executive Summary; and Programmatics, Cost and Schedules Report, respectively.

First Order

BASIC PLATFORM FAMILY



Second Order

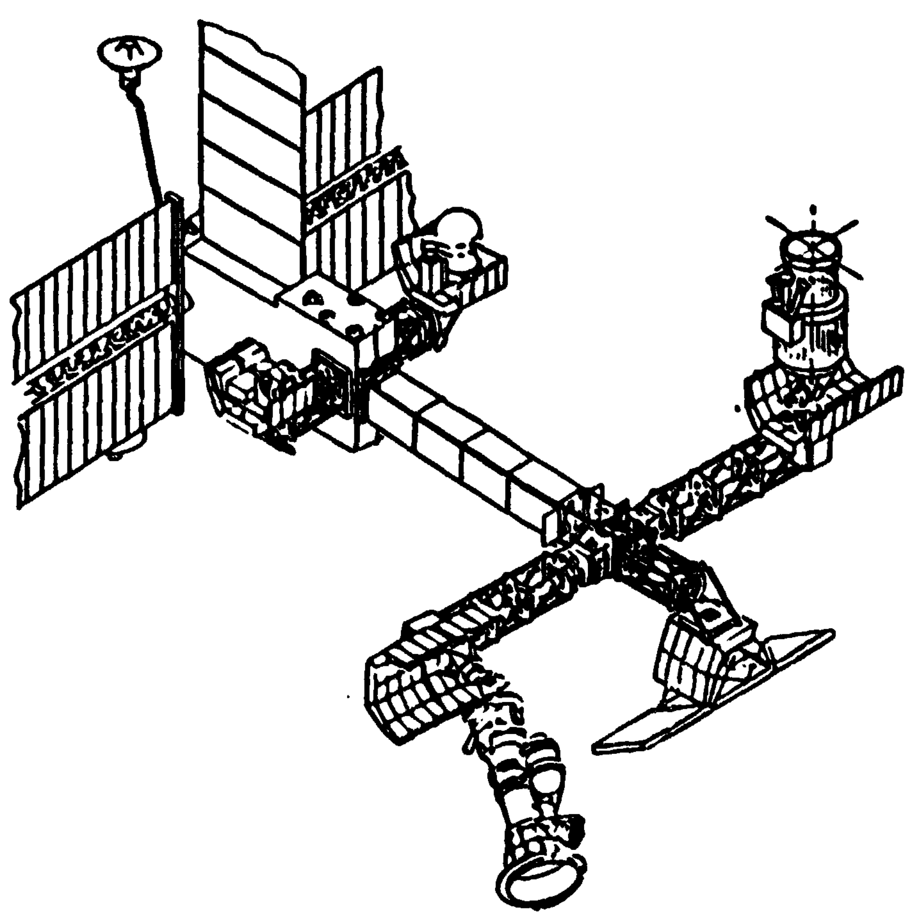


TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

Starting in the mid-1980's, platforms in low-earth orbit will provide highly beneficial and adaptable accommodations for a great variety of science and applications payloads.

This document contains the results of a one-year Phase A concept study of such a platform (attached to a Power System) conducted for NASA/Marshall Space Flight Center by the McDonnell Douglas Astronautics Company - Huntington Beach.

The platform configuration conceived in this study consists of a two-part evolution as shown in Figure A. The First Order Platform consists of minor appendages to the Power System for improved payload viewing, whereas the Second Order Platform is designed to accommodate more and larger payloads.

The platform design philosophy is as follows:

- Provide a highly-modular system for:
  - low cost initial utilization with extended-duration Spacelab payloads.
  - conservative escalation of mission capability.
  - flexible adaptation to the great variety of payload sizes, groups, and orbits being planned.
- Maximize payload integration simplicity and flexibility of Platform use.
- Optimize division of labor between platforms, Power System, and payloads.

Such a long duration, multipayload, free-flight Platform will not only be beneficial to many payloads, but also to certain overloaded mission support elements such as data relay satellites. Figure B illustrates the modular elements of the Platform System.

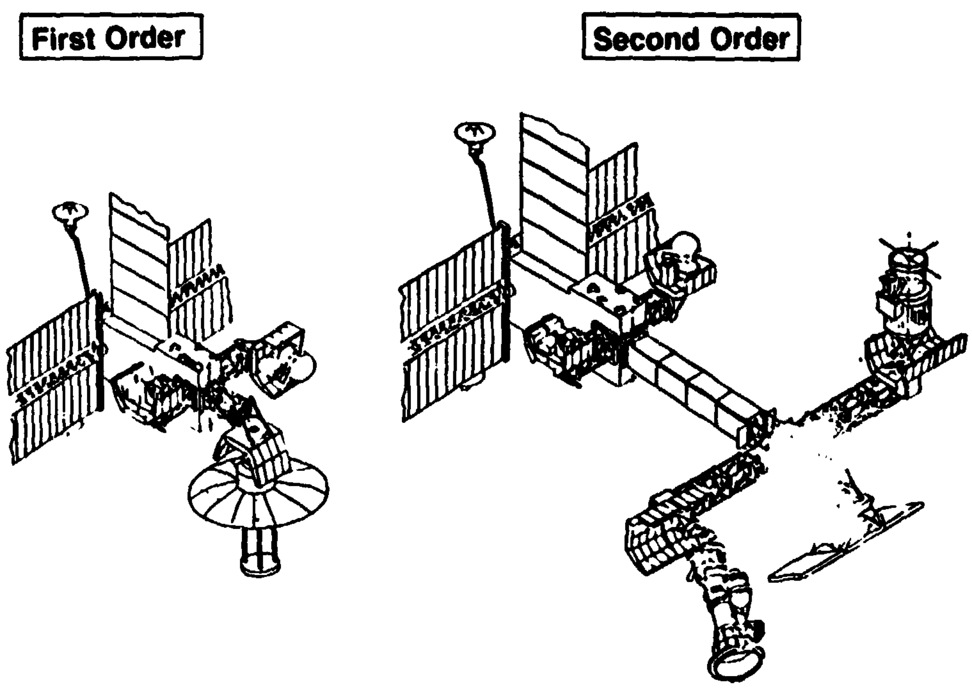


Figure A Evolutionary Platform Concept

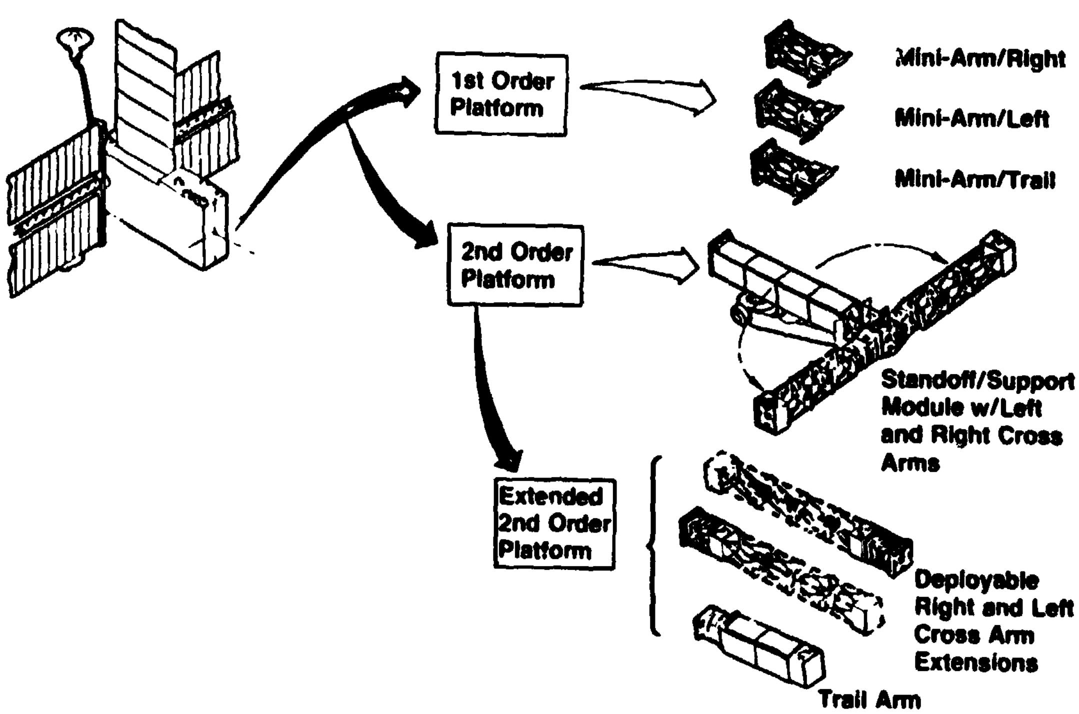


Figure B Platform Parts Catalog

Payloads which will particularly benefit from platform flight include the following:

- Payloads which have similar orbit altitude and inclination requirements.
- Payloads whose budgets preclude investment in dedicated free-flyers.
- Payloads which have previously flown on Spacelab pallets for short durations in the Shuttle sortie mode and desire long duration flight, a more benign environment than Shuttle, and minimal transition for payloads and their original pallet installation.
- Payloads whose flight durations are in a range of a few months to a few years, or those requiring periodic earth return, on-orbit modification, maintenance or replenishment; wherein, costs of dedicated spacecraft and multi-rendezvous Shuttle services would be prohibitive for solo-flown payloads.
- Payloads which when grouped for maximum synergism are of significant size and constitute a multi-Shuttle delivery operation and thus, require a centralized orbit rendezvous, assembly, and resource facility.

In general, the Platform provides economy for the payloads community by virtue of (1) the centralized provision of resources, (2) long-term availability as a "rental" facility for long- or short-term users, and (3) a single orbital address for Shuttle to support a number of payloads as opposed to the multiple rendezvous prospects of separate spacecraft per payload.

Although the Platform has a broad spectrum of potential utilization, it is not generally conceived as a vehicle for those payloads which have extremely unique orbits or payloads which would have or create untenable interfaces with the Platform by virtue of physical or operating features or sensitivities.

This Phase A study followed and capitalized on an extensive Pre-Phase A study by NASA in-house at MSFC, and also paralleled a major portion of a TRW study of platform payload prospects.

The overall objectives and flow of the study covered in this document are shown in Figures C and D; the latter expanded in a detailed task flow in Appendix A at the end of this document.

The overall conclusions of the study are as follows:

- The platform configuration shown in Figure A can effectively support from 80-85% of the NASA/OSS and OSTA payloads planned for the mid-to-late eighties from a performance standpoint (earlier NASA programmatics analyses indicated considerable cost benefits for payloads with the platform mode versus dedicated free-flyers for each payload).
- The modularity shape and size of the recommended platform concept offers:
  - a low-investment, early capability option to demonstrate system performance.
  - flexibility for conservative growth as needs or funds permit.
  - adaptability in configuration arrangement to a great variety of multi-discipline, dedicated discipline, or application modes.
  - good dispersion and viewing freedom for payloads up to 12 meters in length.
- The subsystem approaches recommended are based on a logical and cost-effective distribution of labor among payloads, Platform, and the Power System.
- Although most candidate payload definitions/requirements are currently sketchy, the great number and diversity of payloads (50-60) accommodated by the recommended platform concept [illegible] a sound basis for the concept.

- **Develop Concept for a Long Duration Free-Flight Platform in Low Earth Orbit to Provide:**
  - **Effective Accommodations for a Broad Variety of Payloads**
  - **Flexibility for Dedicated or Multi-Discipline Payload Groups Which Have Large Differences in Size and Schedule**
  - **Capabilities That Extend and Complement Those of the Power System**
  - **Routine, Dedicated Use of Orbiter for Delivery, Revisit and Exchange**
- **Capitalize on OSS and OSTA Payload Definitions, Updated User Inputs, the Prior MSFC In-House Study and the Concurrent Payload Assessment Study**

Figure C Study Objectives

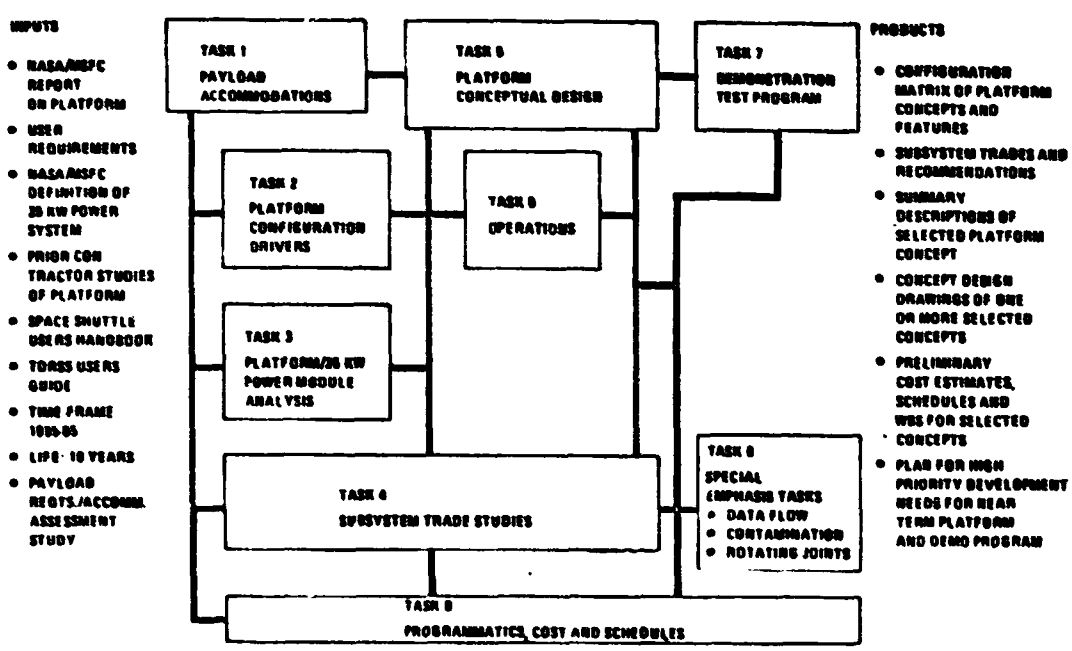


Figure D Study Task Flow

- The T-bar and cruciform configurations inherent in the recommended Platform, with rotary joints on each leg, provide very good viewing, separation, and loading features for payloads.
- Deployable structures offer stowage compaction advantages for long arms but structural modeling for analysis and development testing is required.
- Stabilization of 1.5 arc seconds can probably be achieved with an instrument pointing system for payloads with platform structure selected.
- The impacts of transition of Spacelab sortie payloads to platform flight can be kept to a minimum.
- Shuttle RMS support of platform deployment and loading requires a special berthing arm for the extended span reaches involved or RMS relocation.
- The reference Power System used in the study fulfills most Platform/payload requirements but numerous minor changes are required.
- The study raised many design and operational issues which require more detailed analysis in the future to better address (1) the emerging interface definition needs of the recently-initiated Phase B Power System study,and (2) the accommodation needs of representative mission scenarios, recently outlined in the companion TRW study.

From a payload standpoint, therefore, the prospects of flying on first and second order versions of a Platform, offer a beneficial progression of orbital accommodations after Spacelab flights, as indicated in Figure E. This escalating capability provides an effective combination of a minimal impact, major improvement in payload accommodations, long-duration unmanned flight, increasing separation of payloads, provision of man for activation, loading and servicing, centralized, extensive resources, and periodic, single-destination use of Shuttle, all shared economically and used at will on a rental basis by many different users through the years.

The remainder of this document (Volume II of III) is divided into sections corresponding of the first eight of the nine tasks in the study. The ninth task is covered in a separate volume (III) entitled "Programmatics, Costs and Schedules". An Executive Summary of the study is also published in a separate volume (I).

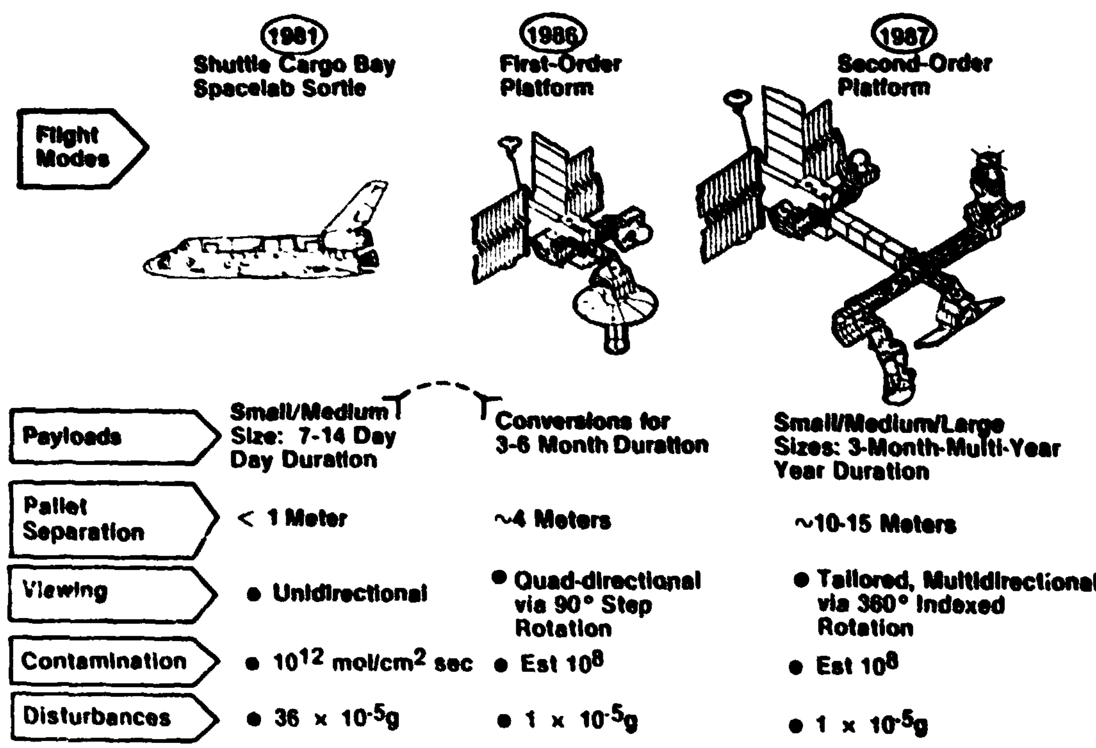


Figure 3 Progression of Payload Accommodations

Section 1
PAYLOAD ACCOMMODATIONS
(Task 1)

1.1 PAYLOAD REQUIREMENTS

Individual payload requirements for the Platform are documented in references 1-1 through 1-5, as provided by the NASA offices of Space Science and Applications. Figure 1.1-1 illustrates the total payload data base as it was computerized in our study, including Materials Processing Payloads (R-01 through R-04) from reference 1-3. Significant data base updates were made twice during the study, based on new information provided by NASA. Although requirements data will continue to change and improve for some time to come, as payload concepts become actual designs, the broad envelopes of requirements created in this study constitute a good representation of the payloads of the late 1980's and thus, a good basis for platform conceptualization.

Figure 1.1-1 SASP Payload Data Base

To simplify requirements analyses these data were put into computer format for the MCAUTO-CONFIRM program which is a Conversational File Information Retrieval and Management System. Data subsequently presented in Section 1.3 were developed using the CONFIRM computer capability. Figure 1.1-1a illustrates the vast differences in character of typical platform payload candidates.

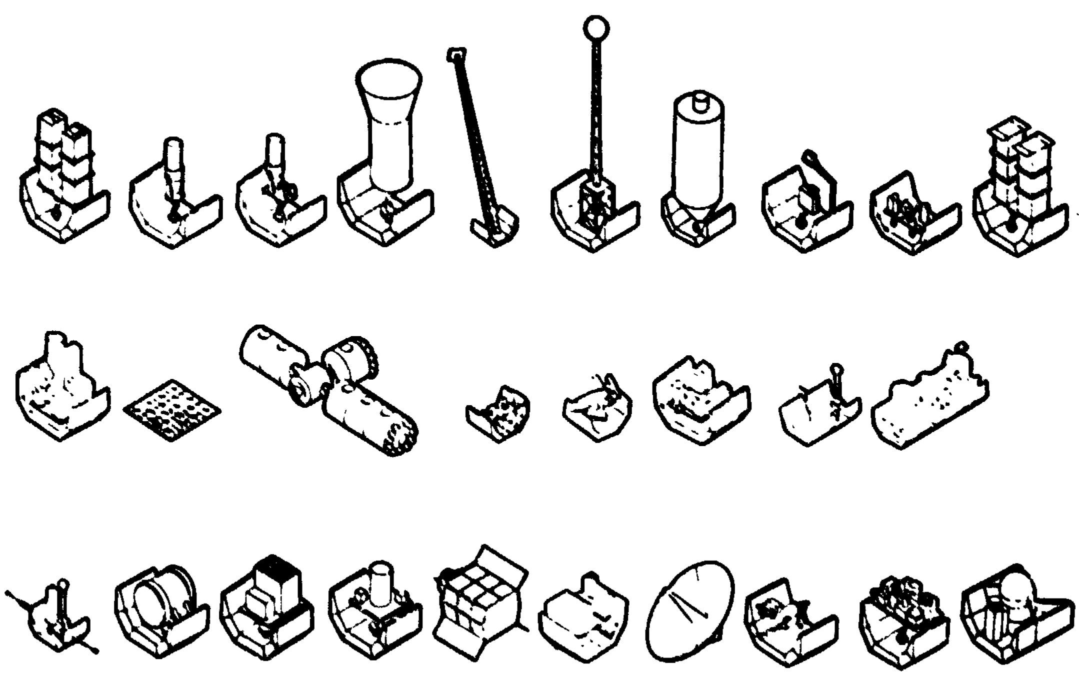


Figure 1.1-1a Typical Platform Payloads

1.2 PROGRAM OPTIONS

Since program-level mission considerations were called for by the Statement of Work, a range of program options were initially investigated, as shown in Figure 1.2-1. Initial reporting on Program Option B was provided at the early reviews. Figures 1.2-2 and 1.2-3 illustrate preliminary payload power requirements for platform sizes for three sets of 2, 3, and 4 pallets each. Following the First Quarterly Briefing, the requirements effort was redirected

toward definition of requirement envelopes only, in lieu of continuing the effort on representative program option sets.

PROGRAM OPTIONS	PLATFORM LOCATIONS
A	PLATFORMS AT 28.5° AND 90° (BASELINE CASE IN MDAC/OSP STUDY)
B	PLATFORMS AT 28.5° (2), 57° (2) AND 90° (USED AS EXAMPLE IN THIS SECTION)
C	PLATFORMS AT 28.5°, 57°, 70°, AND 90°
D	PLATFORMS AT 28.5°, 57°, 70°, AND 90°, AND SUN SYNCHRONOUS
E	PLATFORMS AS NEEDED PER USER GROUP
F	PLATFORMS AS NEEDED FOR USERS WITH COMMON VIEWING INTERESTS

CRITICAL AREAS

IDENTIFY PAYLOADS CLEARLY UNSUITED TO PLATFORM

DEVELOP COMPATIBLE PAYLOAD GROUPS FOR EACH PROGRAM OPTION

NUMBER OF PALLETS/ PAYLOADS PER PLATFORM

Figure 1.2-1 Program/Platform Orbit/Quantity Options

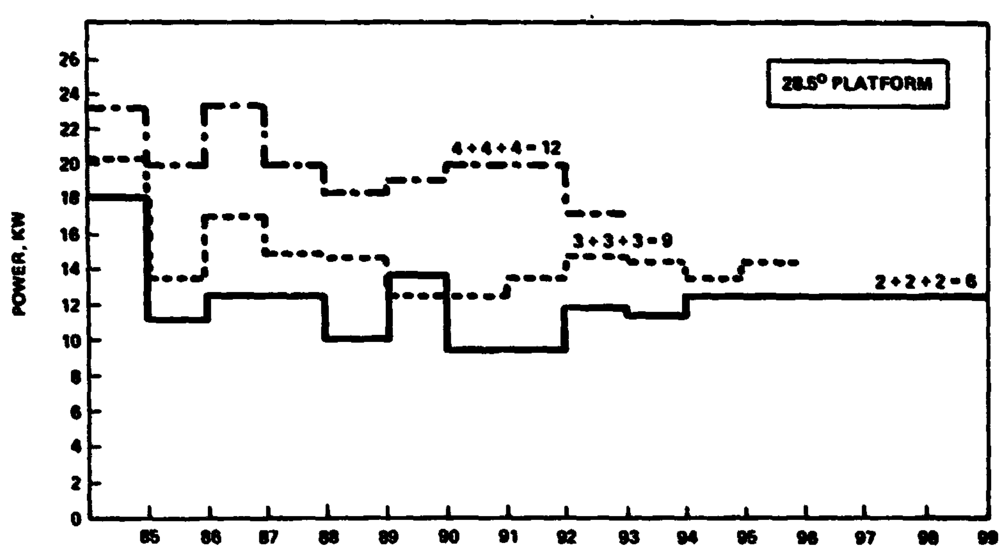
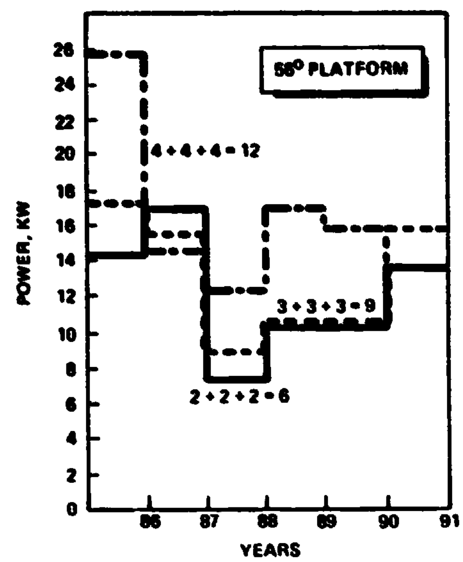


Figure 1.2-2 Platform Power Vs Platform Size



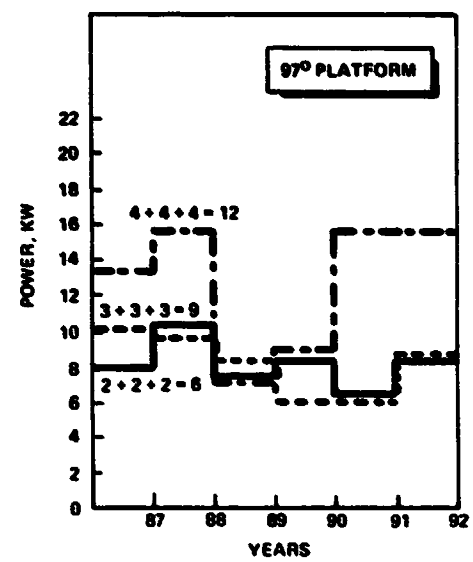


Figure 1.2-3 Platform Power Vs Platform Size

1.3 PAYLOAD REQUIREMENT ENVELOPES

Payload parameters contained in the NASA Data Base Reports, were ordered computerized and analyzed to generate requirement envelopes as seen in Figures 1.3-1 and 1.3-2, Average Power-Viewing Payload. These charts exclude Material Processing and Life Science payloads (non-viewing) from the determinations; however, examples of power requirements for these payloads are shown in Figure 1.3-3a. Manned versions of those two payloads involve a manned access module with requirements as indicated in Figure 1.3-3b. The payload power data incorporated 500 watts of power for Instrument Pointing Systems, as required to meet accuracy and stability requirements. These payload power requirements were assumed to include any necessary computer, input/output and support electronic power. This assumption was found to be incorrect and an increment of 707 watts was added to reflect avionics requirements and higher IPS consumption. Similar requireme . envelopes were prepared for the following:

Pointing accuracy

Pointing stability

Peak power

Data rates

Contamination

Charts presented later in appropriate section.

Payload mass

Payload size

Payload availability

Payload minimum lifetime (desired)

See Figures 1.3-3c, 1.3-3d, 1.3-3e, and 1.3-3f, respectively.

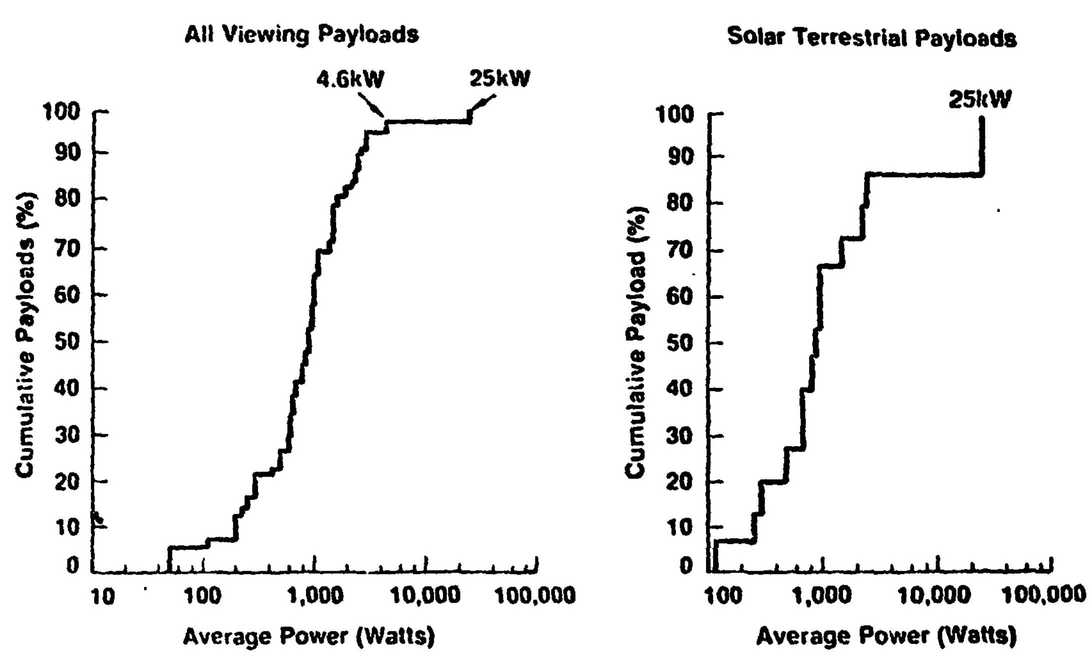


Figure 1.3-1 Average Power - Viewing Payloads
(Includes IPS Power for Stabilization $\leq 0.5°$)

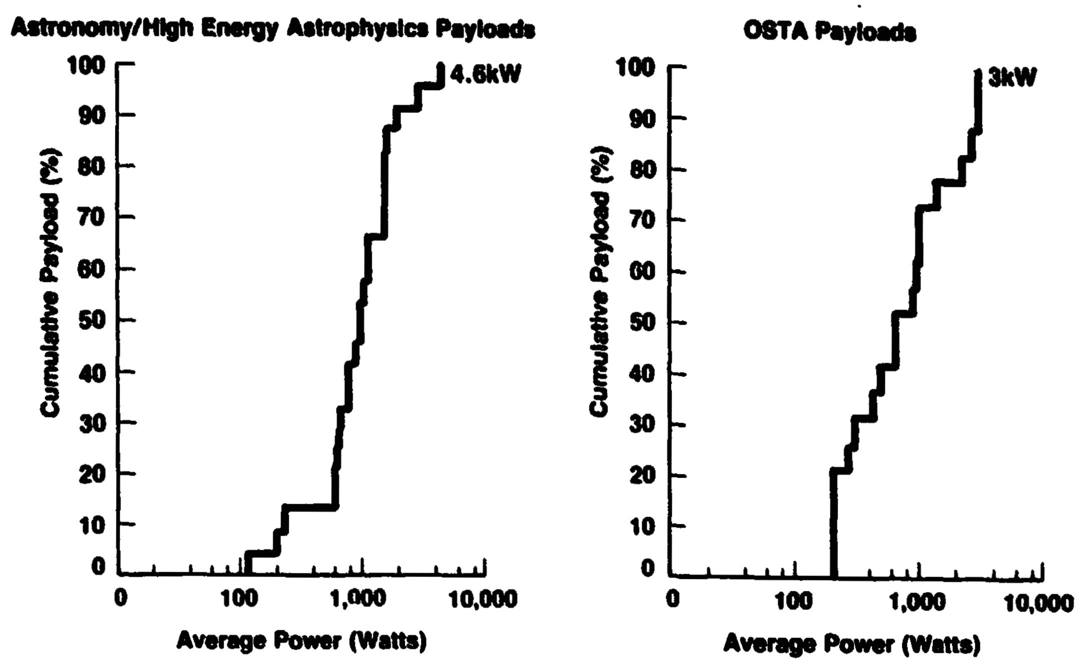


Figure 1.3-2 Average Power - Viewing Payloads (Continued)
(Includes IPS Power for Stabilization ≤0.5°)

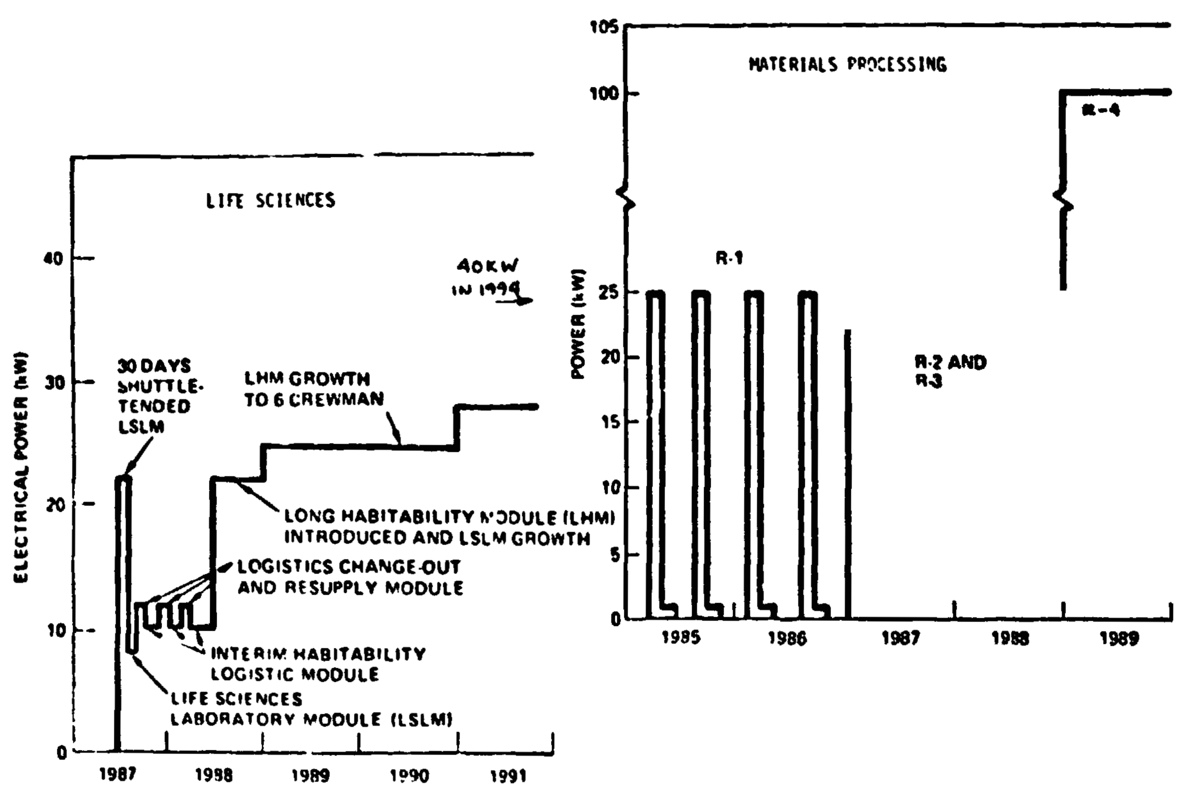
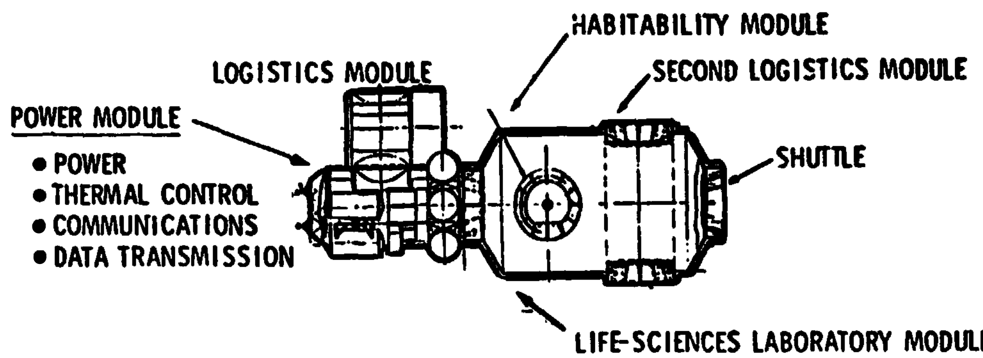


Figure 1.3-3a Power Requirements Life Science and Materials Processing



- PROVIDES PRESSURIZED (SHIRTSLEEVE) TRANSLATION BETWEEN VARIOUS DOCKED MODULES: SHUTTLE, LIFE-SCIENCES LABORATORY MODULE, HABITABILITY MODULE, AND 1 OR 2 LOGISTICS MODULES
- SERVES AS CONNECTING LINK FOR POWER, THERMAL CONTROL, COMMUNICATIONS, AND DATA TRANSMISSION BETWEEN THE POWER MODULE AND OTHER DOCKED LIFE-SCIENCES MODULES
- SERVES AS A STORAGE UNIT FOR ATMOSPHERIC GASES AND OTHER SUPPLIES AND EXPENDABLES NEEDED FOR LABORATORY OPERATION

Figure 1.3-3b Manned Access Support Module

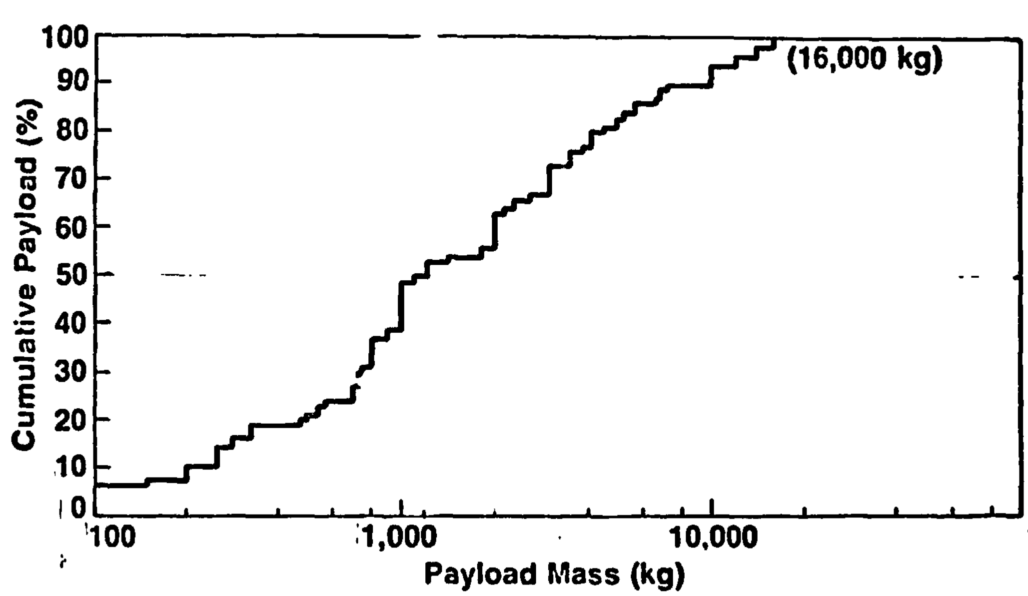


Figure 1.3-3c Payload Mass Vs Cumulative Percentage

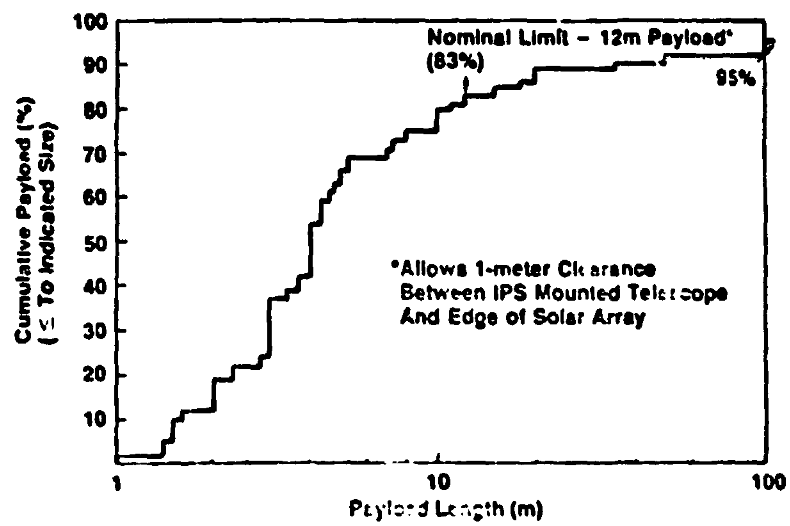


Figure 1.3-3d Maximum Payload Size

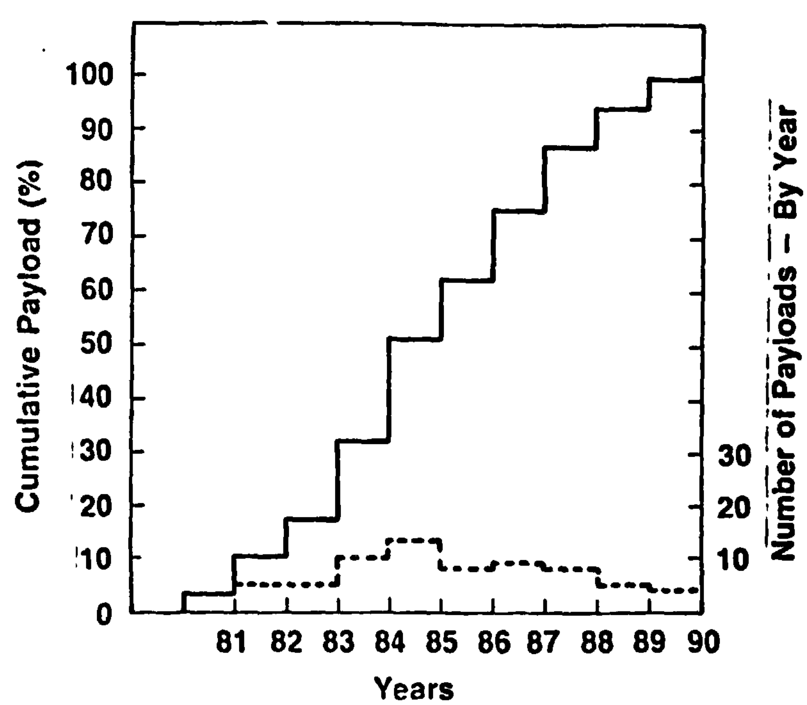


Figure 1.3-3e Payload Availability

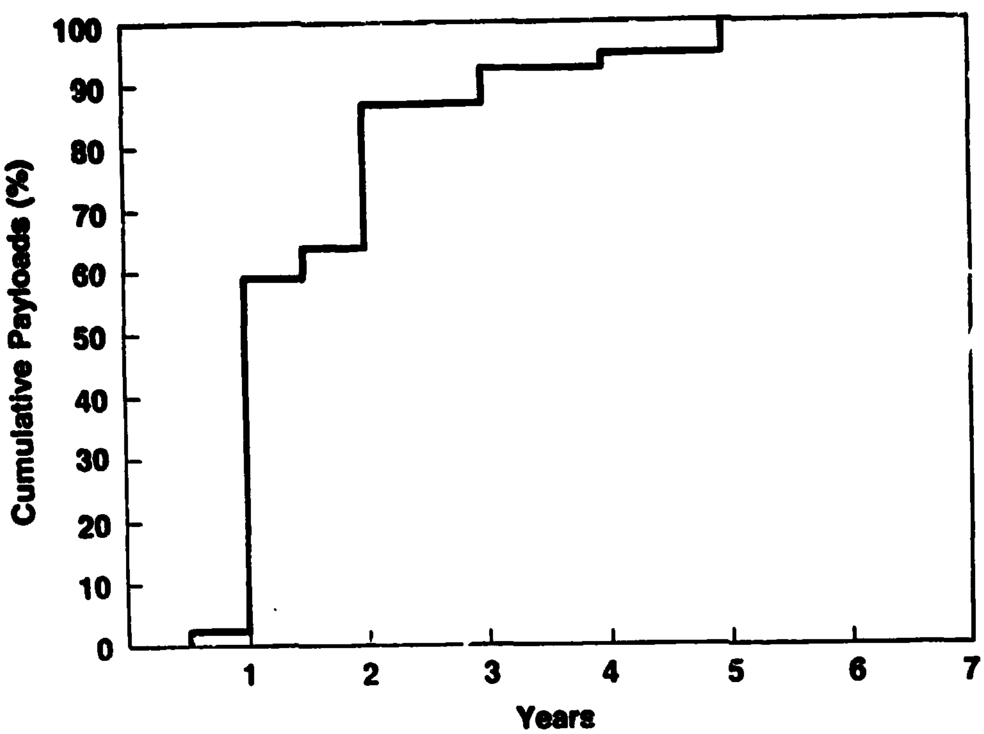
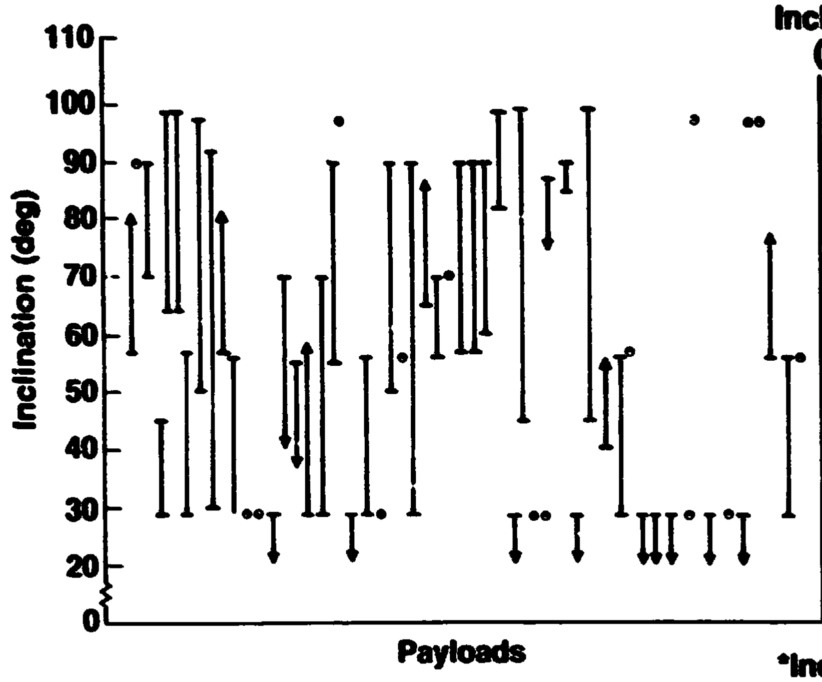


Figure 1.3-3f Minimum Mission Lifetime Desired
(Viewing Payloads)

In addition, payload inclination and altitudes ranges were plotted (Figures 1.3-3g and 1.3-4a) to determine orbit capture over normal ranges. Each chart includes a capture percentage as a function of altitude or inclination. This determination was made using the data plotted from references 1-2, 1-3, and 1-4. The ranges were obtained from the minimum, maximum, and desired values as contained in the referenced payload requirements. The altitude preference peaks at 400 km while inclination preferences peak at 28.5° with lesser preferences seen at 70, 90, and 56 degrees. Similar results were observed for plots of desired payload altitudes and inclinations.

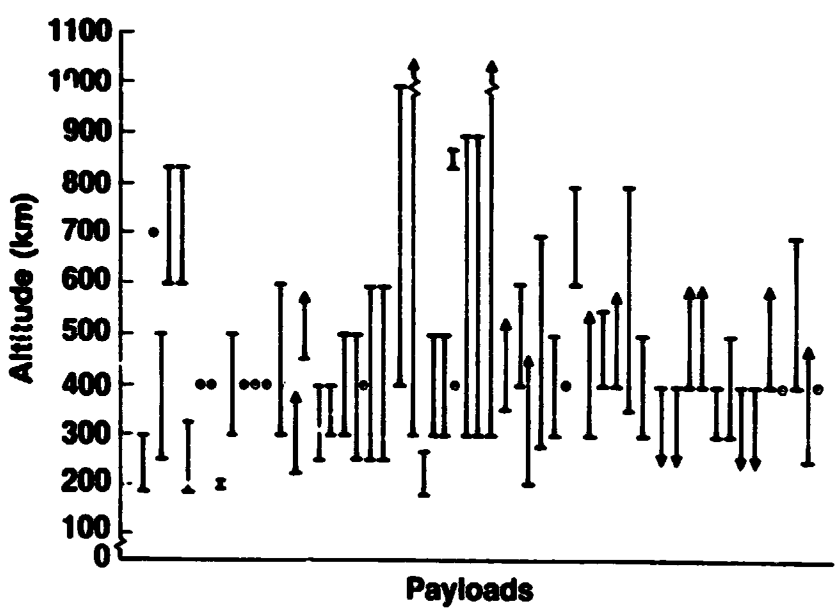
The foregoing types of data were used to establish requirement bounds and to develop rationales for system/subsystem sizing. For example, cross-arm standoff from the Power System and docking port separations distances were



Orbit Inclination (deg)	Percent* Captured
98	26
97	34
90	44
70	47
57	39
56	42
30	29
28.5	53

*Includes 5 "Any" Inclinations

Figure 1.3-3g Inclination Ranges and Capture



Orbit Alt (km)	Percent* Capture
900	28
850	30
800	34
700	39
600	44
500	57
400	84
350	54
300	54
250	30
200	20

*Includes 3 "Any" Altitudes

Figure 1.3-4a Altitude Ranges and Capture

established from analysis of maximum payload dimensions. This analysis is covered in Section 2.0, Configuration Drivers (Task 2.0). In addition, many interfaces between the Shuttle and the Platform create configuration shaping requirements. A depiction of these is given in Figure 1.3-4b.

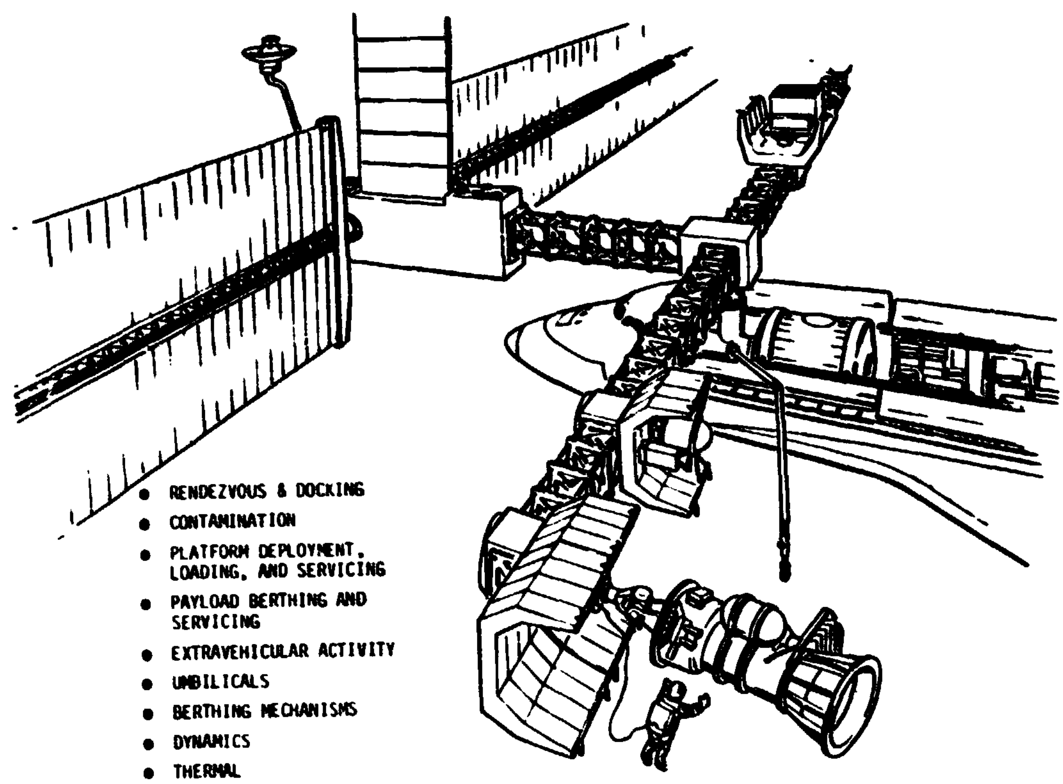


Figure 1.3-4b Shuttle Interface Requirements

1.4 EVOLUTIONARY CONFIGURATION CONCEPTS

The Science and Applications Space Platform (SASP) may begin its support role directly as a minimal augmentation to the Power System. This lowest cost option would then evolve as mission requirements dictate. Such a low cost start to accommodate three payloads is illustrated in Figure 1.4-1a. Payload Berthing System arms should be attached to the X and ±Y docking ports on the Power System to assure viewing freedom and physical separation from nearby

equipment. Each arm should have a 0° ± ⌞.⌟ rotation about the ports center line plus a 90° hinge action which allows orientation along the center line or at 90° to the center line. Figure 1.4-1a also lists system/subsystem capabilities needed for such a first order configuration. Next, as shown in Figure 1.4-1b, the fast growing size of payloads in the late1980's calls for a larger Platform of the type shown in Figure 1.4-2.

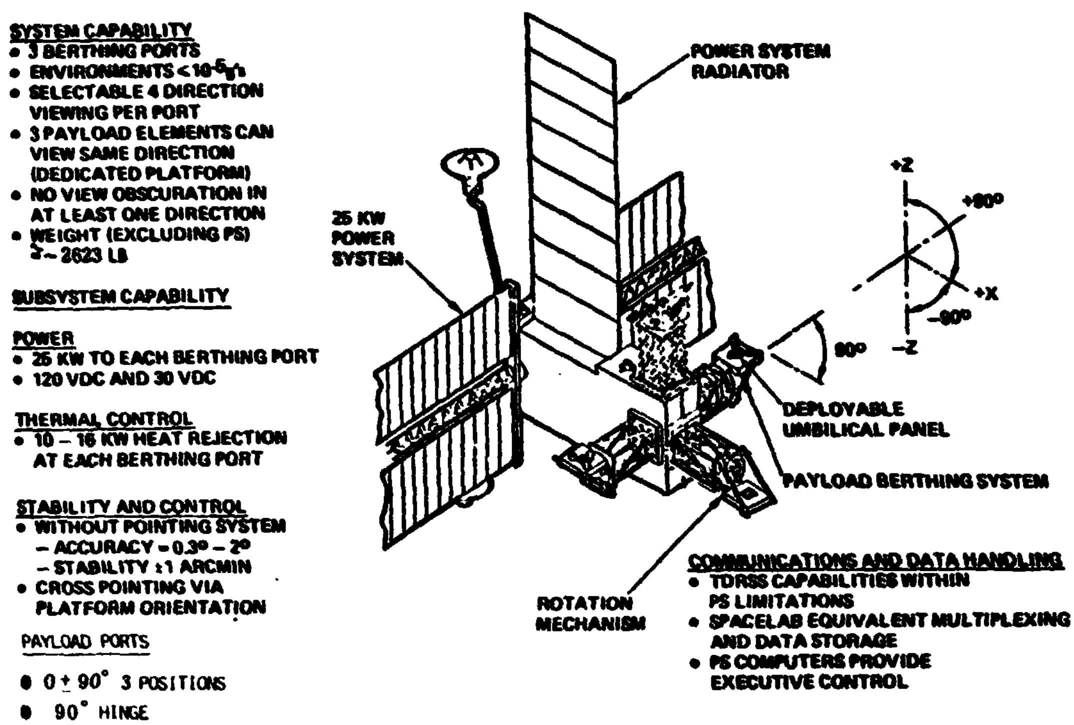


Figure 1.4-1a First-Order Platform

FIRST USE	PAYLOAD SIZE Volume: m³ (No. of Pallets)	Mix Through 1990	FLIGHT ACCOMMODATION
1981	<10 (<1)	20%	SHUTTLE SORTIE • Payloads in Cargo Bay
1981	10-30 (1)	45%	
1984	30-90 (2-3)	20%	
1986	90-150 (4-5)	15%	FIRST ORDER PLATFORM • 3-meter Arms/1 Payload Each
1987			SECOND ORDER PLATFORM • 24-meter Arms/2 Payloads Each
1990	Very Large Payloads (25-100-meter Diameter)		ADVANCED PLATFORM • 48-meter Arm with Construction Aids

Figure 1.4-1b Growth in Viewing Payloads and Accommodations

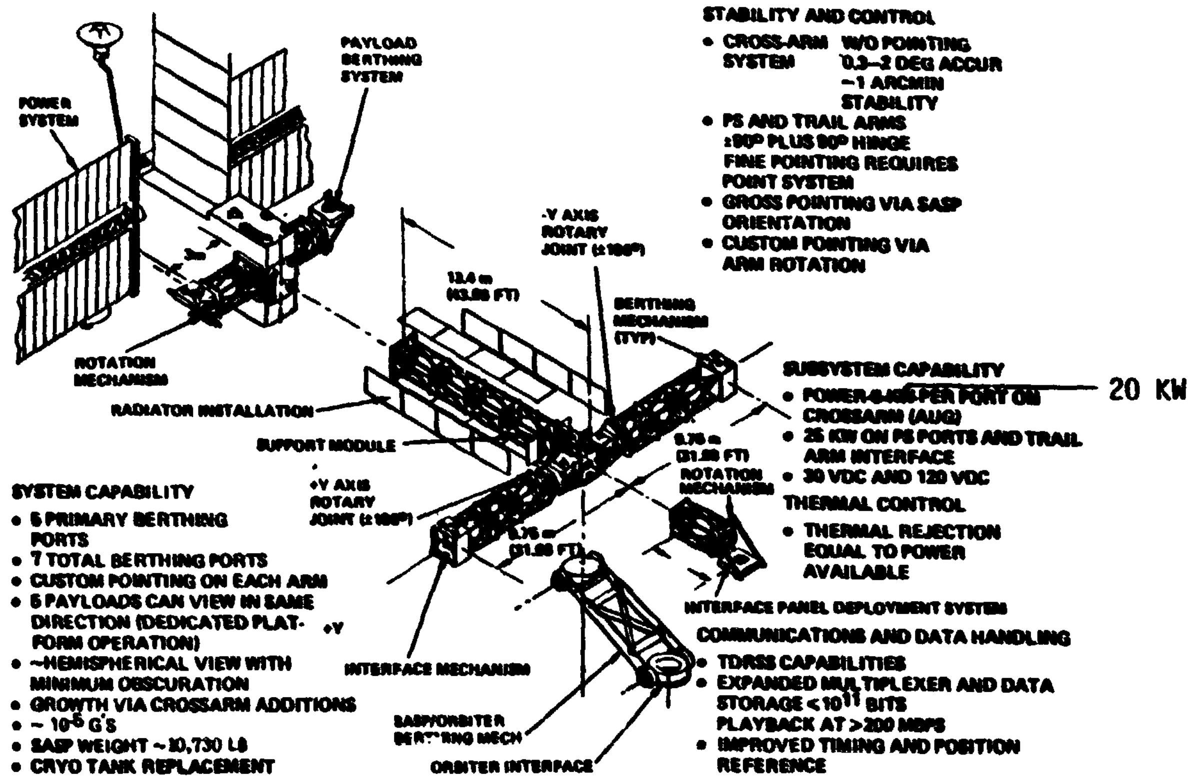


Figure 1.4-2 Second Order Platform

Capabilities of an extended second order platform for more payloads is summarized in Figure 1.4-3a and Figure 1.4-3b shows additional configurations of various modular assemblage, for differing anticipated mission needs. The modular approach to platform growth is summarized in Figure 1.4-4 which shows the hardware elements involved in the first, second, and extended second order platforms, each progressively accommodating greater numbers and sizes of payloads. The standoff structure, support module, plus left and right cross-arm structures, are shown as the first growth steps to accommodate more and large payloads. Subsequent growth involves addition of left and right cross-arm extensions plus a trail arm kit for even greater payload support capability. Continued, i.e., non-dead-ended use of the First Order Payload Berthing System Arms is shown for each configuration.

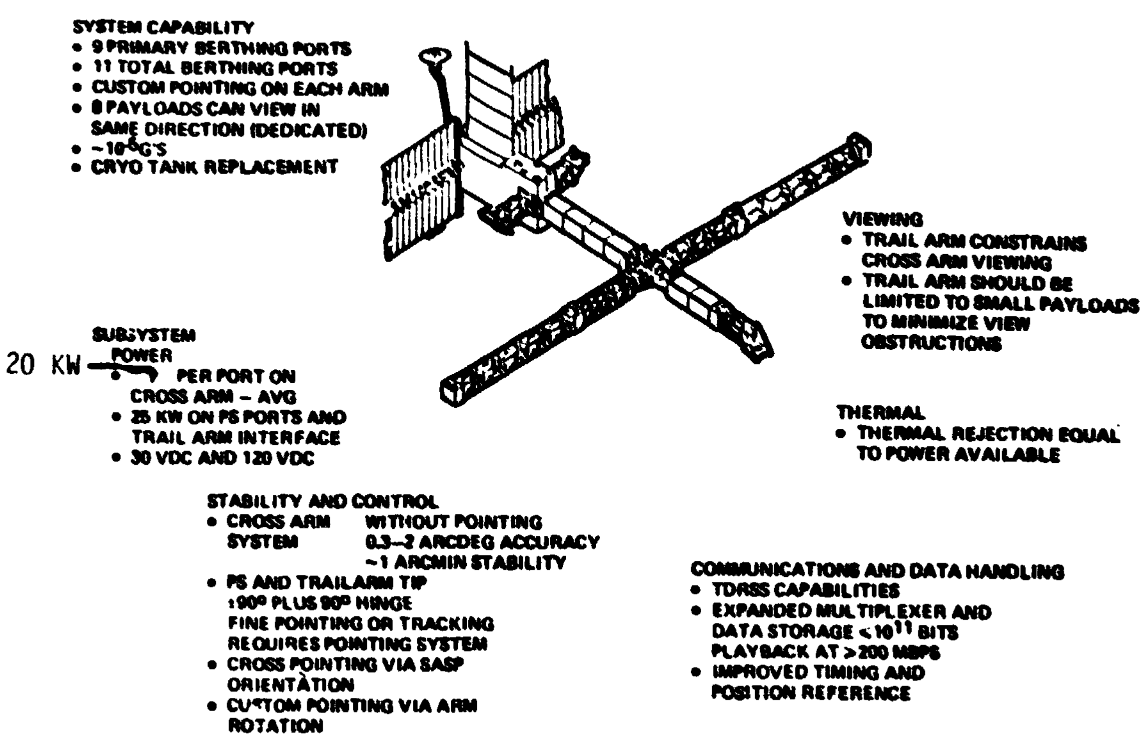


Figure 1.4-3a Extended Second Order Platform

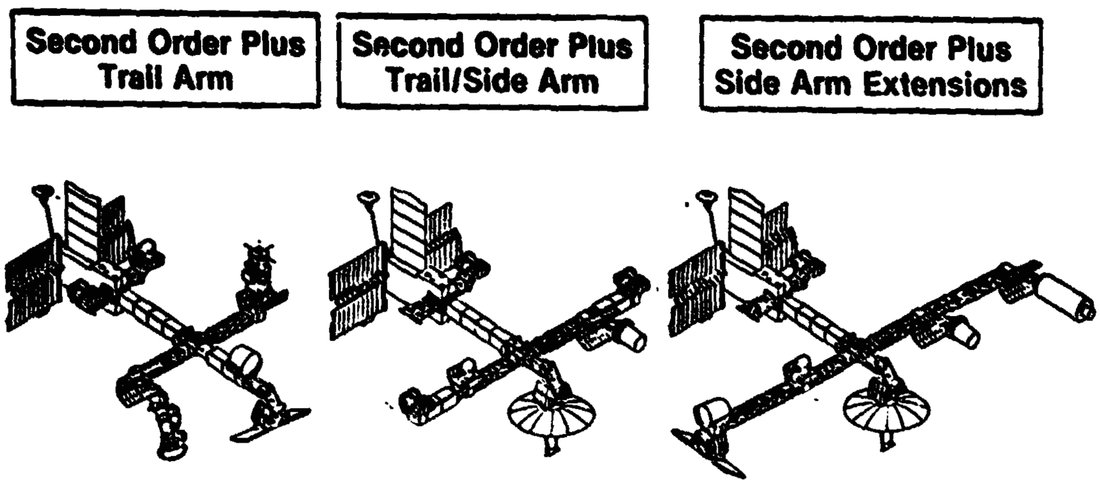


Figure 1.4-3b Extended Platform Family

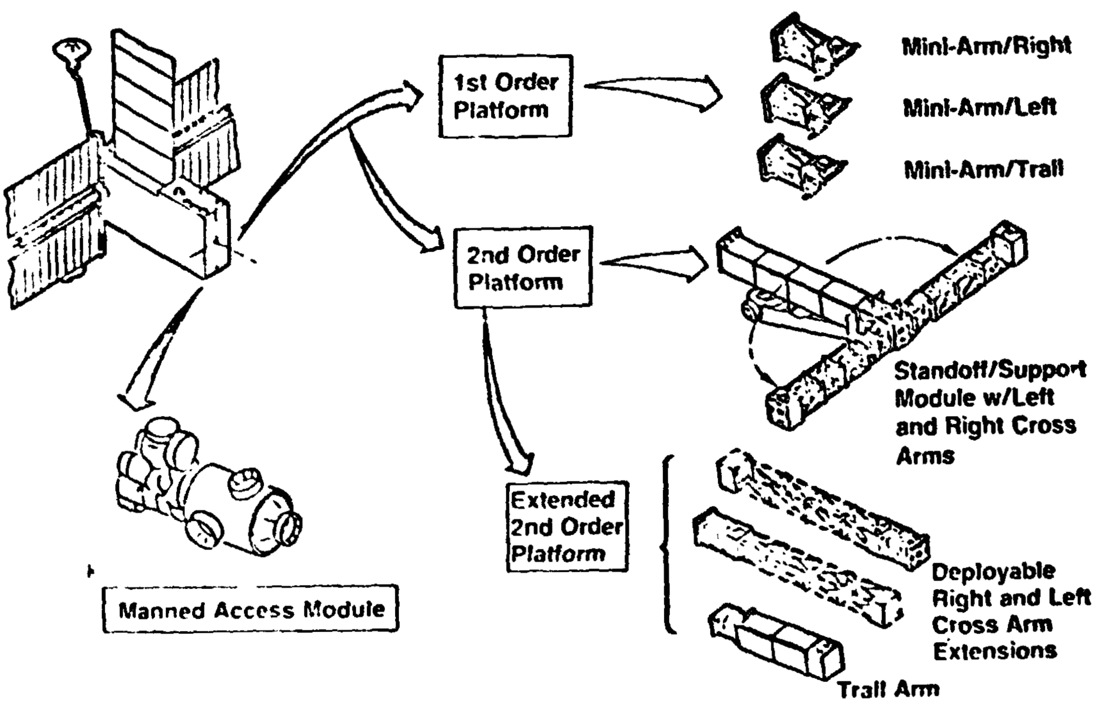


Figure 1.4-4 Platform Parts Catalog

1.5 PAYLOAD ACCOMMODATION EXAMPLES

Many general accommodation assessmentswere made early in the study and finally two TRW mission cases were studied in detail. Payload scenarios presented in the second TRW Quarterly Review, reference 1-6, were examined to determine sample accommodation feasibility of our Platform concept. Cases were addressed for both First and Second Order Platforms.

1.5.1 First Order Platform Accommodation of TRW Sample Mission

Figure 1.5.1-1 represents Flight Scenario I and this schedule was examined to determine First Order Platform accommodation. Difficulty is encountered first in the 4th quarter of 1985, when a total of seven payloads are scheduled at once. With a maximum of four payload docking positions (+X, $\pm$Y, and +Z), there is no room to dock the two free-flying payloads (CRM and SPP-2). Thus, if these two payloads are to fly at the same time, they must be launched and retrieved by the Orbiter. EO-1 assumed to be mounted on the solar array wing boxes; however, there is some question whether the required pointing accuracy of 0.5° can be met since the array pointing system does not require this level of pointing accuracy. Further, during Z-LV orientation skewing of the principal axes (for altitude control) may align these payloads outside their desired 0.5° pointing accuracy.

The scenario cycles viewing requirements so that Z-LV orientations (X-POP at high beta and Y-POP at low beta) are necessary to satisfy the earth viewing payloads. Solar viewing is intermittent at low beta angles. The nominal X-POP, Y-PSL orientation, is unsatisfactory for the combined earth solar viewing, but is required routinely to satisfy celestial viewing needs.

In a number of instances the payload schedule requires three direction viewing. (E.g., Magnetic, Earth and Solar plus Solar, Earth and Celestial.) The First

Order Platform cannot satisfy these requirements continuously, but can satisfy these requirements for varying periods of time depending on actual view directions needed at each port.

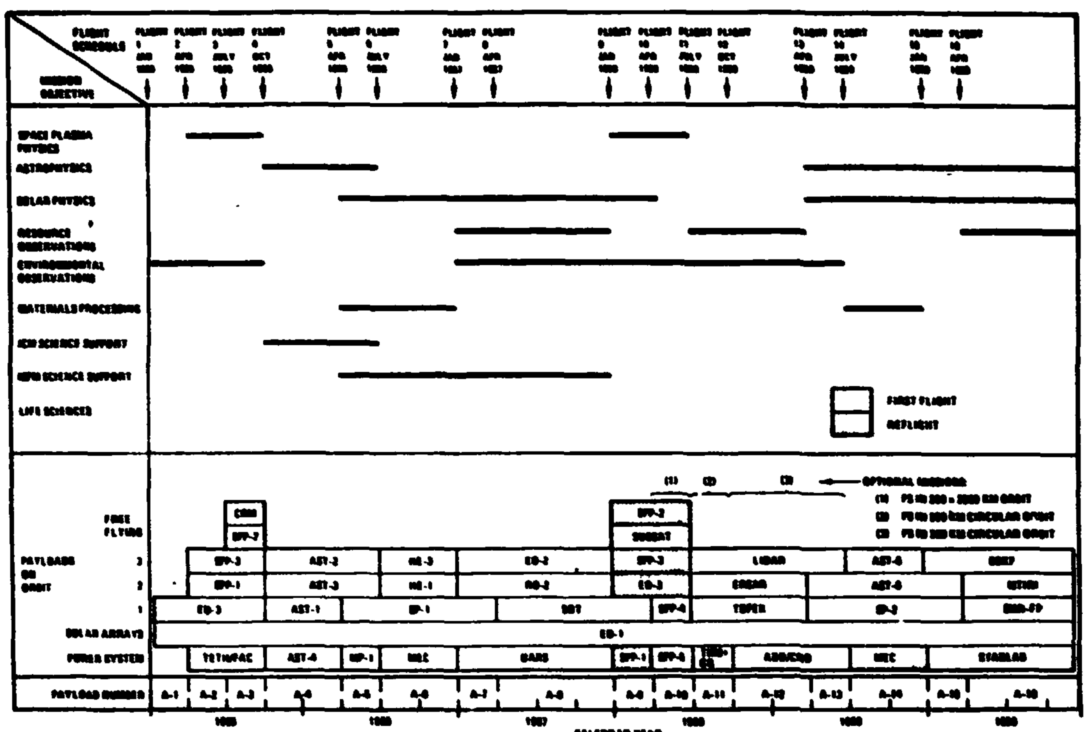


Figure 1.5.1-1 Flight Scenario I - First Order Platform
57°, 400 KM Orbit

This scenario encounters minimum view obscuration; however, SMR-FP (R-34) is an earth viewer that is 20 meters in diameter that would obscure other earth viewing payloads. The only feasible location for this payload is on the +X docking port where reorientation will be necessary to permit Orbiter docking. Some size difficulty is associated also with ERSAR (R-42), which should also be loaded on the +X docking port. This particular payload wants to look perpendicular to the velocity vector; thus, the Z-LV, X-POP (high beta) is necessary when this payload is operated.

The reference scenario was examined to determine the number of times that a full Orbiter launch would require a special payload stowage position to permit payload changeout. During the six year period, there were four instances where a special payload stowage arm (on the Power System) would be necessary. This analysis assumed all four docking ports would be used. Since there has been question about the usefulness of the +Z port (view obscuration and safety limits on instrument travel), Flight Scenario I should be re-examined for both three and four port capability and on a basis of growth to a Second Order Platform in the second or third year of operation. The requirements for the payload stowage arm should then be reassessed since scheduling options could obviate the need for an expensive Power System element.

1.5.2 Second Order Platform Accommodation of TRW Sample Mission

Flight Scenario II from reference 1-6 was given to us as a representative program for the Second Order Platform. A vertical slice was made at Payload Number B-10 (third quarter 1987) for purposes of an accommodation analysis. Figure 1.5.2-1 provides top level requirements for the selected payloads. A range of platform configurations were examined to select the one which satisfied the B-10 case most readily. Figure 1.5.2-2 illustrates the extended platform case with cross-arm kits which readily meets the payload requirements. It is necessary to fly the configuration in a Z-LV orientation. Consequently, there are limitations on solar viewing during periods of low beta angle and ERSAR (R-42) would require a payload pallet gimbal to allow continuous viewing perpendicular to the velocity vector for both high and low beta angles.

The acceptability of EO-1 solar viewing within 0.5° is the same as discussed above for the First Order Platform.

Code	Title	View Direction	Point Accuracy	Remarks
HE-1	Meyer Cosmic Ray	Anti-Earth	2 Deg	
HE-3	Cosmic Ray Instr.	Anti-Earth	2 Deg	
EO-1	Environ. Observ.	Solar	0.5 Deg	Mount on Solar Array Boxes
MP-2	Solidif. Exper. System	None	NA	~Zero-G
SP-1	Sol. Physics Pallet	Solar	10 Sec	IPS Required
SMIP-3	Sol. Optical TSC. (SOT)	Solar	1 Sec	IPS Required
R-34	Soil Moisture Rad. (SMR-FP)	Earth	1 Deg	
R-42	Earth Resources SAR (ERSAR)	Earth	2.5 Deg	Point Perpendicular to VV

Figure 1.5.2-1 B-10 Payload Requirements
(3rd Qtr '87)

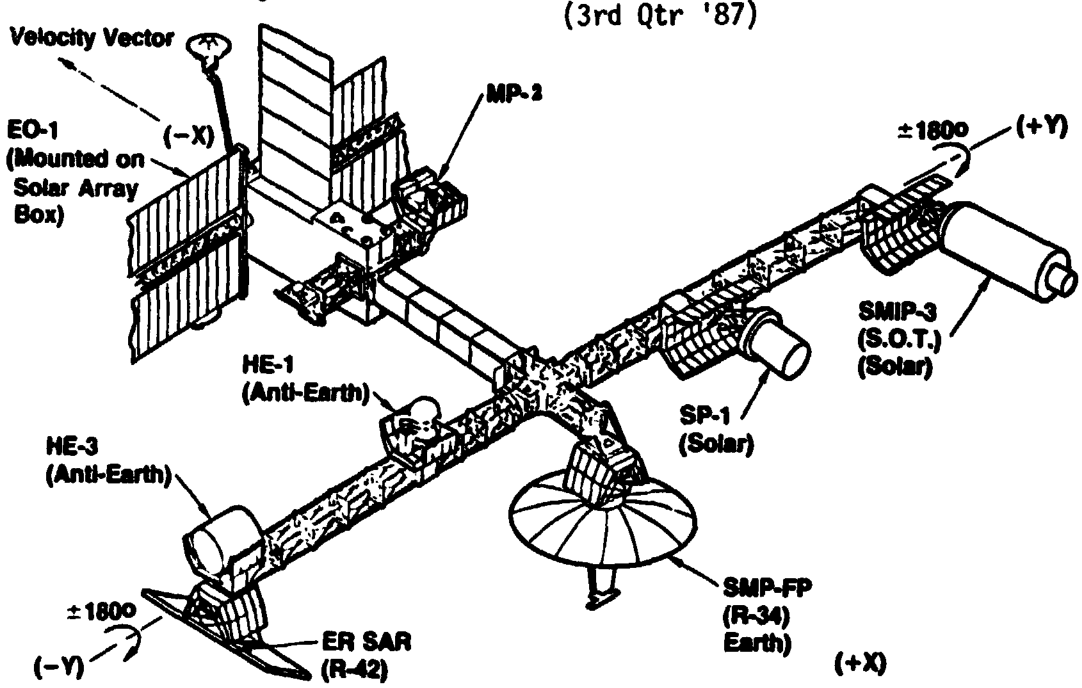


Figure 1.5.2-2 2nd Order Platform - Payload B-10 Accommodation

Cross-arm standoff from the Power System and spacing between adjacent docking ports was established on a basis of maximum payload dimensions. The B-10 payload segment illustrated in Figure 1.5.2-2 falls well within the nominal size limitations developed in Section 2 (Task 2 - Configuration Impact). A random sampling of nine payload sets was made on Flight Scenarios II and III. Of these nine scenario sets, seven of them involved oversized payloads which have been recommended as extra-long trail arm payloads only. Of these seven cases, four would require additional gimbal constraints to prevent collision risk between payloads on adjacent docking ports. Briefly, these payloads are as follows:

CODE	TITLE	SIZES (METERS)
AOI-2	Astrometric Telescope	18 X 2D
AMIP-5	IR Telescope	35 X 15D
SP-5	Pinhole Camera - 1	100 Boom
SOI-3	AGWA	100D
SOI-1	Particle Beam Injection	100 X 100 X 10
SOI-4	Magnetic Pulse (Geo.)	1000 Antenna
SPP-3		
SMIP-2	Tether Facilities	100,000 Cable
R-37		

If any of the above payloads are flown on a platform configuration such as shown in Figure 1.5.2-2 gimbal constraints will be required and an orientation such as Z-LV should be flown to preclude inadvertant solar array damage. Clear, SOI-1 and SOI-3 will require separate handling since their sizes would cause collisions with platform elements unless they are docked only at the +X docking position and constrained to a finite view cone in the +X direction.

1.6 SERVICE DIFFERENCES BY CATEGORY

When grouped into five general categories, it is possible to distinguish significant differences in payload requirements or services. These are summarized below because they tend to influence platform configuration shaping decisions considerably.

1.6.1 High Energy Astrophysics and Astronomy

The payload data sheets reveal a nearly constant desire to fly at low inclinations except for HE-3 and AST-4 payloads, which have mid-inclination preferences. Payload viewing requirements fall into the Celestial or anti-Earth category and as a unique set, do not require simultaneous multi-direction viewing. As a consequence, gimbal requirements are reduced. These payloads also indicate the greatest need for consumables such as gas, film, and cryogens or some form of periodic servicing.

1.6.2 Solar Terrestrial

This payload set shows a large variety in desired orbit altitudes and inclinations. Further, they collect..ely require multiple and simultaneous viewing directions (e.g., solar, earth nadir and limb, and magnetic field lines). High level pulse power requirements are found in this category also, and will require special attention. The overall payload set has the most diverse and challenging set of requirements of any group.

1.6.3 Resource and Environmental Observations

These OSTA payloads fall into the medium to high inclination orbit range with a number at higher orbit altitudes. All the payload sensors desire earth viewing and only three payloads requiring solar viewing. The payload set includes a number of large payloads with consequent impact on the platform configuration. Servicing desires appear as the lowest of all payload sets which probably reflects their current mode of unmanned untended operation.

1.6.4 Life Sciences

The life science program is unique in being a continuously manned program with no unique pointing requirements. Rather, constraints are placed on allowable "g" levels (10^{-3}) and platform rotational rates. There are requirements for a manned support module and routine logistics/crew rotation. Expressed power requirements have covered a wide range during the study and generally are high enough to have these payloads operate with a dedicated Power System.

1.6.5 Materials Processing

The materials processing payload definitions have changed significantly and frequently during the study. Power requirements have ranged from moderate to very high (100 kW); thus, some consideration should be given to having these payloads also use a dedicated Power System. This approach is considered reasonable also, due to the low "g" level (10^{-5}) requirements as well as low rates of platform axis rotation. Requirements have been advanced both for unmanned and manned operation. The latter would require facilities and logistics for manned support.

Section 2
CONFIGURATION DRIVERS
(Task 2)

Those items that drive the platform configuration or the platform operation are identified in this section. These drivers have been classified into two sets: (1) those arising from experiment requirements; and (2) those generated by constraints imposed by systems external to the Platform (i.e., Orbiter, TDRSS, and Reference Power System). Figure 2-1 illustrates the variety of interfaces which drive the Platform conceptualization. These drivers are summarized in Figure 2-2. For each driver identified the impact on the Platform is shown and the section of this report where the relevant discussion is presented is referenced in parenthesis.

In the following subsections payload requirement and system level drivers are addressed. (Power System characteristics that impact the Platform are treated in Section 3, Power System Interface, while details of the impact of drivers on subsystem design can be found in the appropriate subsection of Section 4, Subsystem Trades.) Concluding this section are discussions of the derivation of the 1st Order Platform mini-arm concept and the rationale for the size of the 2nd Order Platform.

See Section 10, Conclusions and Recommendations, for summary list of trades and results.

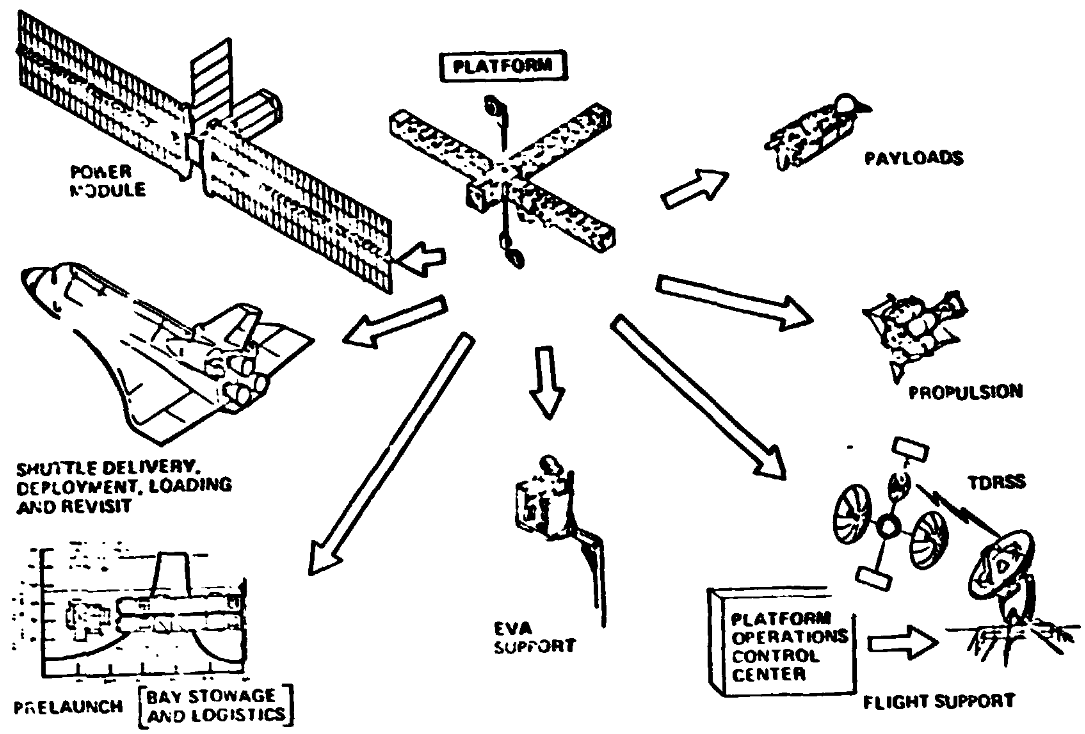


Figure 2-1 Platform System Interfaces

PAYLOAD REQUIREMENTS

- SIMULTANEOUS MULTI DIRECTIONAL VIEWINGS
  - DRIVES OVERALL CONFIGURATION (2.4, 2.6)
- R01 MEC
  - 25 kW POWER DRIVES POWER SUBSYSTEM (2.1) AND THERMAL CONTROL SUBSYSTEM (2.1)
  - 10^{5} LIMIT DRIVES OPERATIONS (2.7)
- PROVIDE HEAT OUT • ELECTRICAL POWER IN
  - DRIVES THERMAL CONTROL SUBSYSTEM (2.1)
- LIFE SCIENCES PAYLOADS
  - 40°F DRIVES THERMAL CONTROL SYSTEM (2.1)
- CRYOGENIC RESUPPLY
  - DRIVES OPERATIONS AND DESIGN (2.1)
- S014 (MAGNETIC PULSE EXPERIMENT)/SPP3 (WAVE PARTICLE INTERFEROMETER)
  - 25 kW DRIVES POWER SUBSYSTEM (2.1)
- R42 (EARTH RESOURCE SAR)/R48 (OCEAN SAR)
  - 120 MBPS DRIVE DATA SUBSYSTEM (2.1)
- R41 (ICE/CLIMATE EXPERIMENT)
  - 25 MBPS FORWARD LINK DRIVES DATA SUBSYSTEM (2.3)
- S011 (PARTICLE BEAM INJECTION) AND S013 (GRAVITY WAVE ANTENNA)
  - 400 - 250 kW PEAK POWER DRIVES POWER AND THERMAL CONTROL SUBSYSTEMS (2.1)
- PAYLOAD SIZE
  - DRIVES PLATFORM SIZE (2.8)
- HIGH ORBIT ALTITUDE REQUIREMENTS
  - SYSTEM PERFORMANCE (2.3)

EXTERNAL SYSTEMS

ORBITER

- SINGLE RENDEZVOUS PER MISSION (2.3)
  - IMPACTS PAYLOAD BERTHING CONCEPTS (4.4)
- RMS REACH AND PAYLOAD MASS CONSTRAINTS (2.2)
  - IMPACTS PAYLOAD BERTHING CONCEPTS (4.4)
- PAYLOAD DELIVERY CAPABILITY
  - DRIVES WTR MISSION OPERATIONS (2.3)
- PAYLOAD LAUNCH ENVELOPE
  - LIMITS FIXED STRUCTURE LENGTH (2.8)
  - CONSTRAINS STRUCTURE CROSS-SECTION (4.8)
- ORBITER EFFLUENTS
  - CURTAILS PAYLOAD OPERATIONS (8.2)

TDRSS

- 50 KBPS (MULTIPLE ACCESS CHANNELS)
  - LIMITS CONTINUOUS DATA DUMP (2.3)
- 300 MBPS (SINGLE ACCESS CHANNEL)
  - DRIVES DATA PROCESSING SYSTEM (2.3)

REFERENCE POW. . SYSTEM

- INTERFACES
  - DRIVES PS TO PLATFORM INTERFACES (3.0)
- 10-16 kW HEAT REJECTION
  - DRIVES THERMAL CONTROL (4.5)
- TWO DEG POINTING ACCURACY
  - DRIVES POINTING (2.5)

Figure 2-2 Platform Configuration Drivers

2.1 PAYLOAD REQUIREMENTS

The primary consideration in configuring the Platform has been to assure responsiveness of the design to payload requirements. In Section 1 the payload analysis task was discussed. The requirements generated there provide the key inputs to the design drivers tasks. Payload requirements that drive the platform design have been identified and are discussed in the following paragraphs. MDAC has carefully reviewed these drivers and, in some instances, recommended not to incorporate those features that would facilitate their accommodation. Two examples of payload requirements drivers, not accommodated by the Platform, but relegated to the payloads themselves are cryogenic resupply and power conditioning for very high peak power loads.

2.1.1 Payloads Requirements that Drive the Thermal Subsystem

Those requirements that depict the thermal design are summarized in Figure 2.1.1-1. The requirement for as much heat dissipation as electrical power impact was voiced by the SASP Scientific Advisory Group. The 40°F minimum temperature for Life Sciences payloads is well below the 60°F minimum that will satisfy other payload classes. 25 kW of cooling for material processing payloads and others is provided on the 2nd Order Platforms. However, MDAC recommends the 1st Order Platform not provide any auxiliary cooling allocating any excess heat rejection above that provided by the Power System to payload. Peak power heat rejection will require either thermal capacitors or operation of the thermal control at elevated temperatures. Cryogenic resupply requirements are not well defined except for a few payloads (see Figure 2.1.1-2). MDAC, therefore, recommends that the ancillary equipment needed be pallet-mounted rather than a standard service provided by the Platform. (Refer to the appropriate thermal control sections for details of pertinent trades and design details.)

- HEAT OUT = ELECTRICAL POWER IN
- 40°F MINIMUM COOLING TEMPERATURE FOR LIFE SCIENCES
- 25 KW PAYLOADS (I.E., MEC)
- PEAK POWER (I.E., GRAVITY WAVE)
- CRYOGEN RESUPPLY

Figure 2.1.1-1 Payload Requirements That Drive the Thermal Control Subsystem

PAYLOAD CODE	TYPE OF CRYOGEN	QUANTITY	RATES	PAYLOAD LIFETIME	COMMENTS
AST 1	SUPERFLUID HELIUM	250ℓ (~30 kg)	[illegible] DAY NOM DESIGN MAX	>1 YEAR	CRYO RESUPPLY EVERY 90 DAYS INSTRUMENT NOT DAMAGED IF CRYOGEN IS DEPLETED
SIRTF (FREE FLYER)	SUPERCRITICAL HELIUM	9000ℓ SC (1170 kg)	--	6 MONTHS	DETECTOR AT 10K
HE 2	TBD	--	--	--	--
AST 3	TBD	--	--	4 YEARS	--
SP 6	SOLID	--	--	~1 YEAR	50 W COOLING AT 100K USING SELF CONTAINED TWO STAGE SOLID CRYOGEN
HE 4	TBD	--	--	1 TO 2 YEARS	--
AOI 2	TBD	--	--	--	CRYO AT 12 MONTH INTERVAL
HE 10/11	TBD	--	--	>2 YEARS (UP TO 10 YEARS)	20 W AT 100K CRYOGENICS OR ACTIVE REFRIGERATION
AMPS	LHE	--	--	--	CRYO AT 12 MONTH INTERVAL
HE 3	LHE	--	--	--	MAY HAVE LARGE SUPER CONDUCTING MAGNET
SPP 2	TBD	--	--	~2 YEARS	--
R 7	LN_2	--	--	--	HAS LN_2 DEWAR
AST 4	TBD	--	--	>1 YEAR	CRYOGENS NEEDED AT DETECTOR
SPP 3	TBD	--	--	1 YEAR	--
AOI 1	TBD	--	--	--	CRYO RESUPPLY
ADD CRO	TBD	--	--	>5 YEARS	--
CRM	TBD	--	--	REUSABLE	--
SUBSAT	TBD	--	--	REUSABLE	CRYO IS MISSION DEPENDENT
AGWA	TBD	--	-- --	~1 YEAR	--
IR TEL	LHE	--	--	~1 YEAR	ONE VISIT PER YEAR MAY BE REQUIRED TO REPLENISH CRYOGENS
LS/LAB	TBD	--	--	7/10 YEARS	--
LUAB	TBD	--	--	7/10 YEARS	--
LOG MOD	TBD	--	--	7/10 YEARS	--
RELATED DATA					
HEAO B	LIQUID HELIUM	300ℓ (~10 kg)		1 YEAR	SUPERCONDUCTING MAGNET
IRAS	SUPERFLUID AND SUPERCRITICAL HELIUM	540ℓ SF (70 kg) 54ℓ SC (6 kg)		1 YEAR	SF AT 1.85K SC AT 5.2K

Figure 2.1.1-2 Currently Defined Cryogen Requirements

2.1.2 Impact of Payload Size

The capability of the Platform to normally accommodate those oversized payloads (several over a km in length) is treated in Section 2.8. If sufficient numbers of large payloads are funded and developed, the trail arm configuration investigated for its growth potential may provide a viable solution. With the current evolutionary configurations these payloads can be flown, but with the Platform dedicated to their operation throughout their residency.

2.1.3 Payload Requirements that Drive the Data Subsystem

Figure 2.1.3-1 illustrates the data rate requirements. R42, the earth resources SAR, and R48 the Ocean SAR experiments, both have 120 Mbps data rates. These synthetic aperture radar payloads drive the data recording and data dump design concepts. R41, the Ice/Climate experiment, defines a need for a 25 Mbps forward link. This rate far exceeds that required by any other payloads and would necessitate the addition of the Ku band forward channel to the Power Systems. Further discussion of these drivers is presented in Sections 5 and 6.

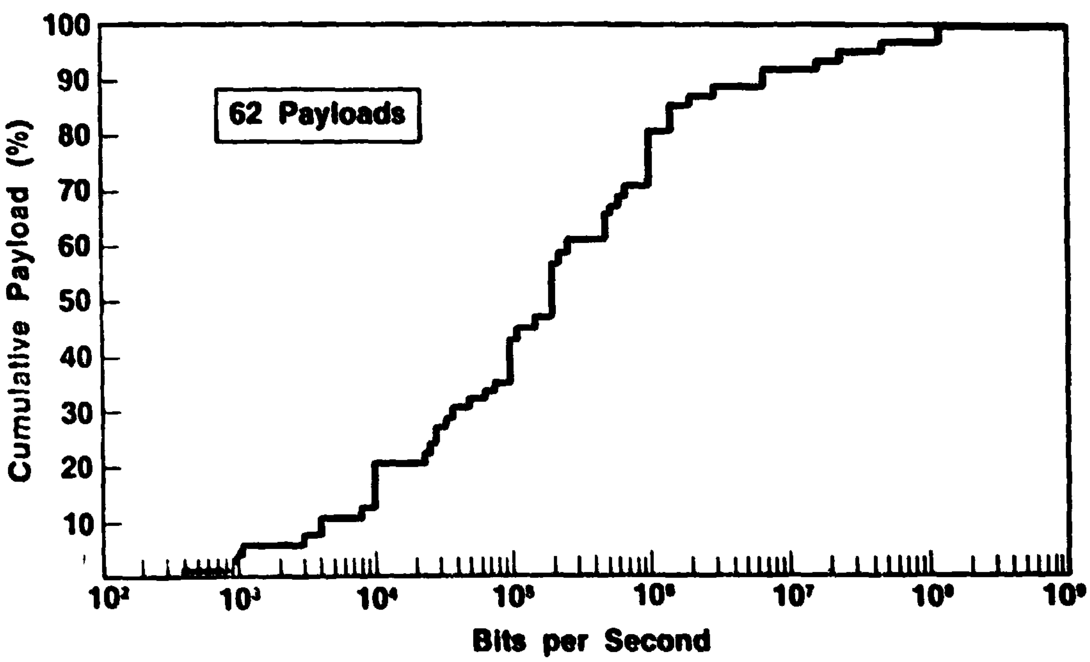


Figure 2.1.3-1 Percent of Payloads Having Data Rate $\leq$X Bits Per Second

2.1.4 Payload Requirements that Drive the Power Subsystem

Distribution of payload power requirements was shown in Figure 1.3-1. In addition to these viewing payloads, there are non-viewing payloads that also drive the subsystem design. RO1 (the Materials Experiment Carrier), SOI4 (the Magnetic Pulse experiment), and SPP3 (the Wave Particle Interferometer) all require 25 kW average power. Figure 2.1.4-1 presents the distribution of peak power requirements. SOI1, the Particle Beam Injection experiment, and SOI3, the Atmospheric Gravity Wave Antenna require pulse peak power levels of 400 and 250 kW respectively. As previously mentioned MDAC recommends these peaking requirements be accommodated on the payload carrier. For relevant trades and design details on peaking power and accommodating the 25 kW average power payloads see the appropriate writeups in Sections 4 and 5.

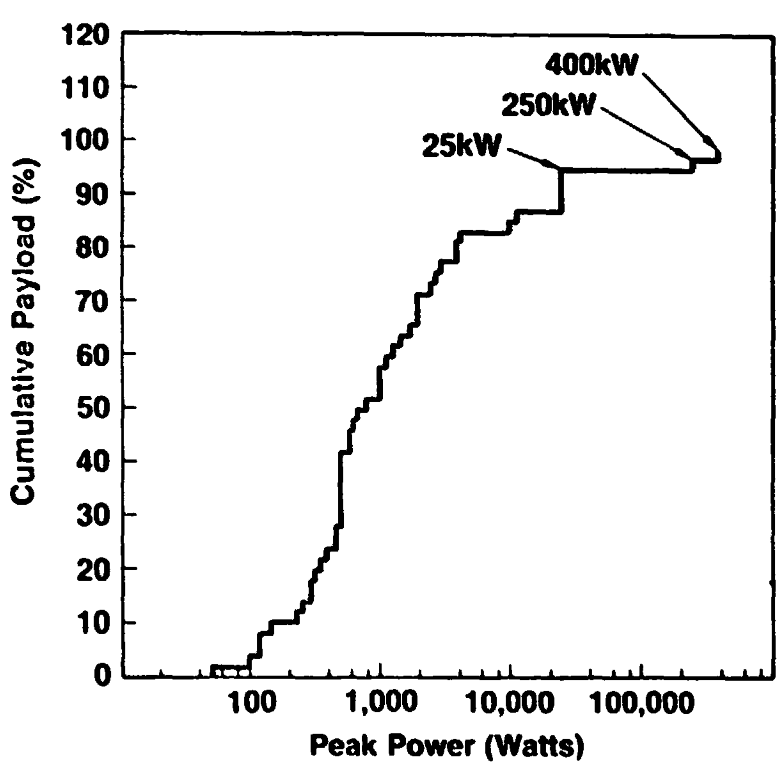


Figure 2.1.4-1 Payload Peak Power Requirements

2.1.5 Payload Requirements that Drive the Attitude Control System

Pointing stability and accuracy requirements for the experiments are summarized in Figure 2.1.5-1. If the decision had been made to accommodate each experiment using only the Platform's capability, almost all would be design drivers. However, employing an experiment pointing system to isolate the payloads from disturbances greately reduced the number of driving payloads. Employing image motion compensation or magnetic suspension techniques to experiments with even tougher requirements effectively relegates the fine pointing problem to the payloads. The ACS drivers are therefore those payloads that lie in the lower half of the box labeled platform capability. The challenge is to accommodate these payloads, HE10 and HE11 for example, without having to mount them on expensive experiment pointing systems.

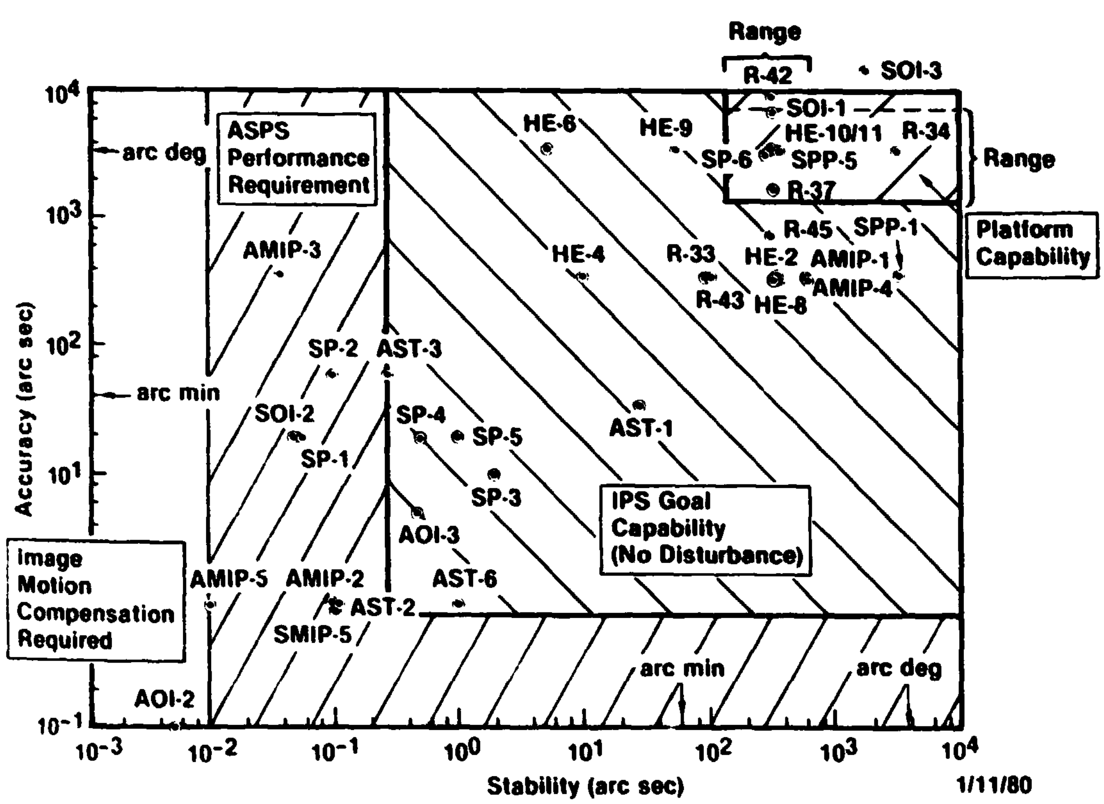


Figure 2.1.5-1 Experiment Pointing Requirements

These requirements drove the design to enhance the inherent pointing accuracy though the addition of auxiliary attitude sensors. In depth discussions are found in Sections 4 and 5.

2.1.6 Payload Requirements that Drive Viewing and Disturbances

The prime factor in designing the platform viewing capability is the requirement for simultaneous multidirectional viewing. The impact of this requirement is addressed in Section 2.4. The governing requirement limiting disturbances is the Materials Experiment Carrier (R01), maximum acceleration limit of 10^{-5} g's. The impact of this requirement is discussed in Section 2.9.

2.2 SYSTEM REQUIREMENTS

Space Platform requirements were derived from the experiment requirements generated by MDAC in Task 1 with additions and revisions from the TRW companion study. A functional analysis of the Platform/Power System combination was performed resulting in the function allocation to the Platform, Power System, payloads, and Orbiter shown in Figure 2.2-1. For this allocation the payload carrier, or pallet, is considered as part of the payload. How these functions have been implemented on the Platform is described in Section 5.0, Conceptual Design. Quantification of these functional requirements and the trade studies that led to the recommended approach can be found in Section 4.0 for each of the subsystem areas.

In this process trades were made to determine where each function should be assigned. For example, providing cryogens or very high power to experiments seemed like desirable services for Platform to provide. However, after evaluating the detailed experiment descriptions and noting the limited number of experiments calling for such services these functions were allocated to the payloads to minimize the overall system cost (see Section 4.0 for details).

TOTAL SYSTEM FUNCTIONAL REQUIREMENTS

- PROVIDE POWER
- PROVIDE THERMAL DISSIPATION
- PROVIDE PAYLOAD POINTING
- PROVIDE COMMAND AND CONTROL
- PROVIDE ORBIT KEEPING
- PROVIDE STABILIZATION
- PROVIDE PHYSICAL SUPPORT
- PROVIDE DATA SERVICES
- PROVIDE SERVICES
  - DELIVERY
  - RESUPPLY
  - MAINTENANCE
  - RETRIEVAL

POWER SYSTEM

- PROVIDE POWER
- PROVIDE THERMAL DISSIPATION
- PROVIDE STABILIZATION
- PROVIDE DATA SERVICES
- PROVIDE ORIENTATION
- PROVIDE STABILIZATION
- PROVIDE ORBIT KEEPING
- PROVIDE COMMAND AND CONTROL

PLATFORM

- DISTRIBUTE POWER DISTRIBUTION
- PROVIDE THERMAL DISSIPATION
- PROVIDE DATA SERVICES
- PROVIDE PAYLOAD POINTING
- PROVIDE PHYSICAL SUPPORT

PAYLOADS

- PROVIDE FINE POINTING
- PROVIDE HIGH QUALITY STABILIZATION
- PROVIDE CRYOGENS
- PROVIDE CONDITIONING FOR VERY HIGH POWER LEVELS
- PROVIDE WIDE AREA VIEWING

ORBITER

- PROVIDE SERVICES
  - DELIVERY
  - RESUPPLY
  - MAINTENANCE
  - RETRIEVAL

Figure 2.2-1 Functional Requirements Allocation

2.3 SYSTEM PERFORMANCE

Design drivers addressed in this section include: Orbiter delivery capability and on-orbit operational constraints; SASP orbit keeping requirements and requirements to achieve unique orbits; RMS capabilities; and TDRSS considerations.

2.3.1 Orbiter Performance

Orbiter delivery performance in the post 1985 frame is summarized in Figure 2.3.1-1 where payload capability has been plotted as a function of circular orbit altitude. For launches to orbit inclinations achievable from ETR, inclinations of from 28 to 57 degrees, the payload capability is greater than 45,000 lbs for the 400 to 450 km SASP altitude regime. This capability is well in excess of that required for delivery of either the SASP or the reference Power System. For sun-synchronous orbits the 25 kW reference Power System weight exceeds the Orbiter payload capability with strap-on liquids for a SASP mission. The scaled down NASA-defined 12.5 kW Power System is

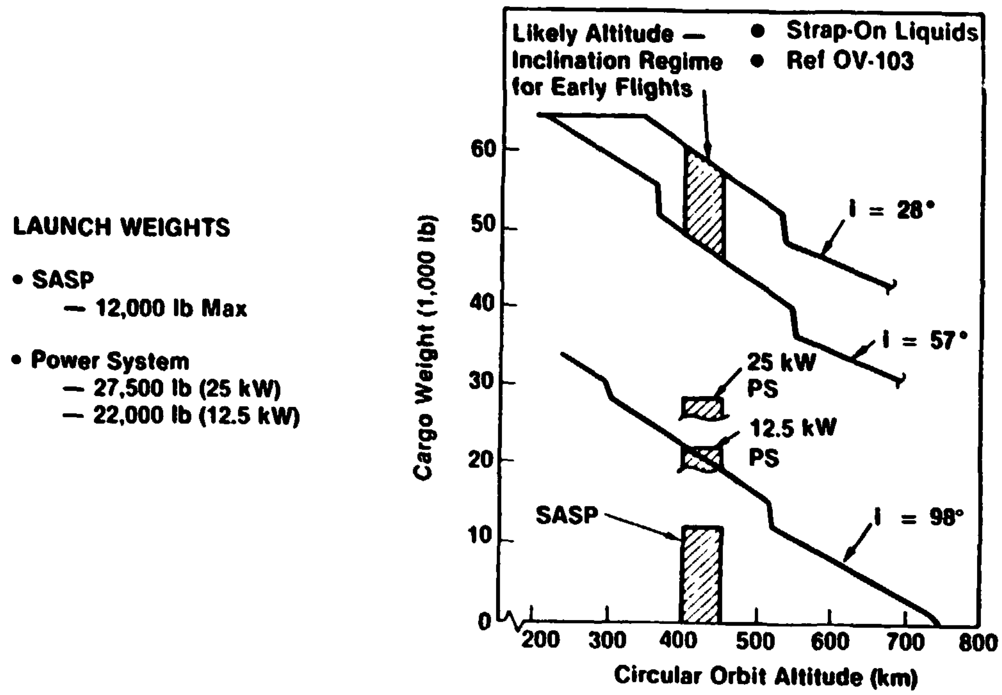


Figure 2.3.1-1 STS/SASP/PS Performance Envelope

marginal while the SASP itself is well within the Orbiter capability. Delivery of the Power System to a lower altitude orbit, with subsequent boost to higher altitudes using internal Power System propulsion or an auxiliary stage are viable modes for achieving the 400 to 450 km SASP orbits or the 700 km and higher altitude orbits desired by many earth resources applications. (See discussion in this section.)

NASA provided information indicates that the Orbiter has the capability to perform only one rendezvous per flight precluding multiple berthing with the SASP for payload changeout, etc.

2.3.2 SASP Orbit Keeping

Results of the orbit keeping analysis show that the factor of primary interest to the experiments reboost frequency can be limited to once every 90 days. Figure 2.3.2-1 parametrically displays the data generated. Only at low

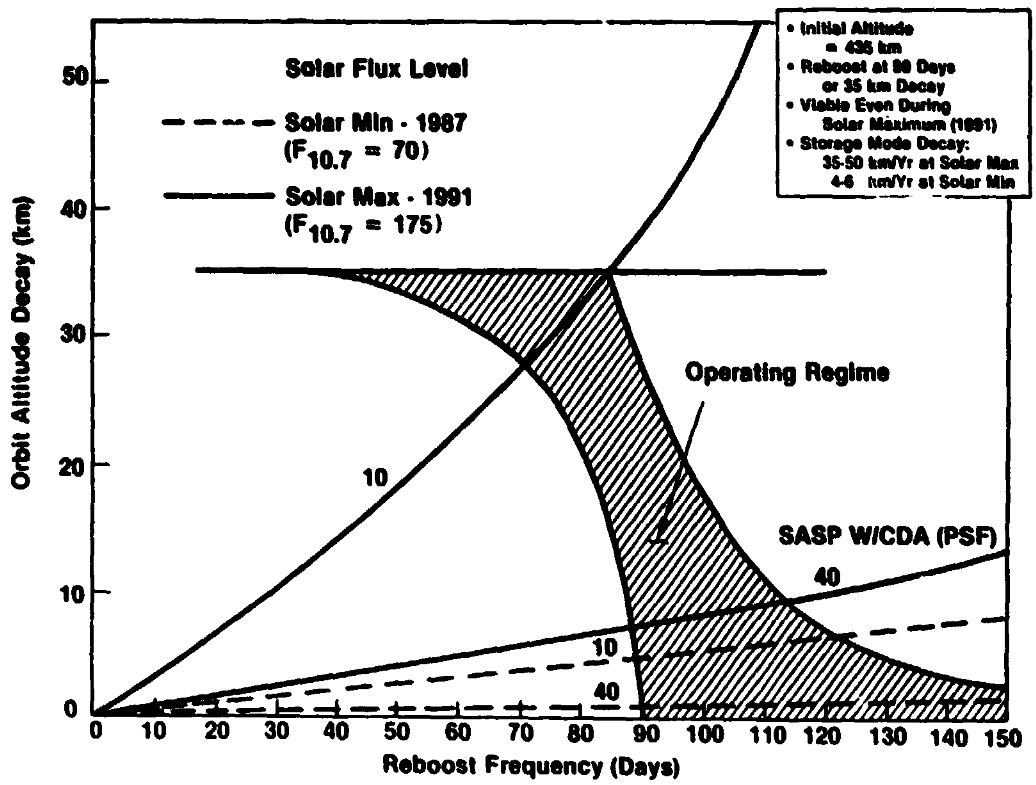


Figure 2.3.2-1 SASP Orbit Keeping

platform utilizati^n (low W/C_DA) and solar maximum atmospheric flux levels, a low probability of occurance combination, are more frequent reboosts required. A higher altitude, 450 km, at the start of the reboost cycle would allow 90 day reboost intervals for even this worst case scenario. Providing this long interval between reboosts benefits the payloads in three ways:
(1) contamination from thruster firings only have to be dealt with infrequently,
(2) high acceleration levels due to thruster firing are minimized, and
(3) experiment interruption due to reorienting for reboost is minimized.

Impact of the Platform on the Power System orbit-keeping propellant requirements should be minor. Since orbit-keeping propellant is a function of drag impulse, not on-orbit weight, the Platform should only add a relatively small drag increment to the Power System.

2.3.3 Unique Orbits

Two special orbits were identified in the companion TRW requirements study. The first, a 705 km altitude, 98° inclination sun synchronous orbit, satisfies many earth viewing experiment requirements. The second, a 200 km by 2000 km elliptical orbit might partially satisfy experiments with either very high or very low altitude requirements. For both of these orbits the key issue is how to achieve the orbit.

In Figure 2.3.3-1 the propellant requirements for achieving the sun-synchronous are shown as a function of platform weight. Several modes are considered: (1) a one-way mission where the Platform and propulsion unit are treated as an expendable payload, (2) the Platform is kept in its high altitude orbit and a TMS employed to ferry payloads up and down, and (3) an elevator mission where the propulsion system stays with the Platform ferrying the Platform between an Orbiter rendezvous compatible altitude and the 705 km operational altitude.

Propellant required to achieve the 200 by 2000 km elliptical orbit is presented in the same format in Figure 2.3.3-2. These data are conservative assuming the propellant cost in terms of impulsive velocity to reacquire the initial 435 km orbit to be equal to that of injection into the elliptic orbit. High perigee drag levels should significantly reduce apogee altitude, therefore, reducing propellant requirements for returning to the nominal orbit.

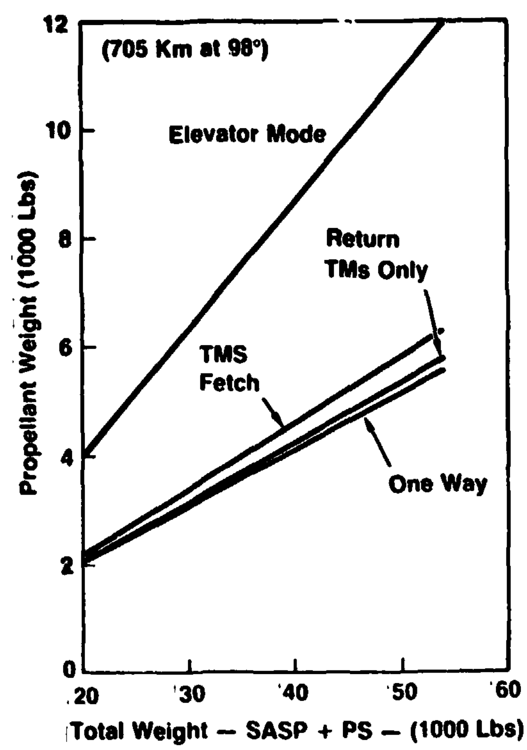


Figure 2.3.3-1 Delivery Cost To Sun Synchronous Orbit

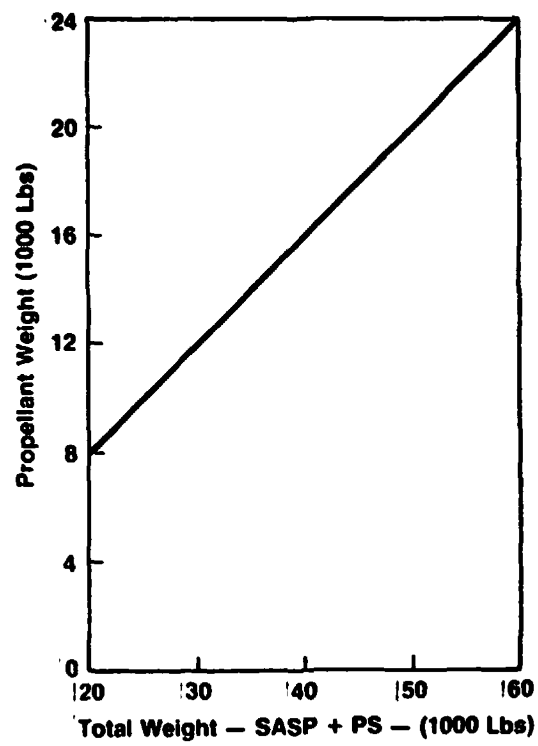


Figure 2.3.3-2 Cost of Establishing Then Leaving a 200 x 2000 Km Orbit

2.4 REMOTE MANIPULATOR SYSTEM (RMS)

The Platform Configuration is influenced by the experiment performance criteria and the operational support required for attachment, removal, component exchange, and maintenance. Access to all payload attach points on any given platform is a primary requirement. The RMS is the major Orbiter subsystem to be used for payload handling. Its technical features listed in Figure 2.3.3-3 have a definite impact on platform design.

RMS TECHNICAL FEATURES

ARM

- 15 in dia. x 50 ft. long
- Mounted (-Y) longeron @ Sta Xo 679.5
- Removable Mass = 905 lb
- Force @ tip = 15 lb minimum
- Torque Available @ wrist roll axis = 230 ft lb
- Stiffness, fully extended = 9.5 lb/in

JOINT MOTIONS

- Shoulder Joint +145 to -2
- Shoulder Yaw +180° to -180°
- Elbow Pitch +2 to -160
- Wrist Pitch +120° to -120
- Wrist Yaw +120 to -120
- Wrist Roll +447 to -447°

PAYLOAD HANDLING

- Max size = 15 ft. dia. x 60 ft. long
- Mass = 65,000 lb
- Tip-off rate = 0.015°/sec max
  10 minutes after Orbiter RCS deactivated
- Max payload velocity relative to Orbiter -0.1 ft/sec

MANEUVERING SPEED

- Max velocity - fully loaded = 0.2 ft/sec
- Max tip velocity unloaded = 2 ft/sec
- Max stopping distance = 2 ft

POSITION ACCURACY

- Automatic Mode ±2 in ±1°
- Manual Mode ±0.5 in

PHYSICAL CHARACTERISTICS

ARM

- General arrangement as defined in Space System Payload Accommodations Handbook #JSC 07700 and shown in Figure 2.4-1.

Figure 2.3.3-3 RMS Capabilities

PAYLOAD INTERFACE

- Payloads to incorporate a grapple fitting, as shown in Figure 2.4-2, and in accordance with #JSC 07700 Handbook. The grapple fixture/ RMS End Effector mating envelope to be as shown in Figure 2.4-3.

REACH ENVELOPE

- Payloads to be placed within the reach envelope defined in JSC 07700 Handbook, paragraph 8.1.1, Figures 8-9.1, 8-9.2, and 8-9.3.

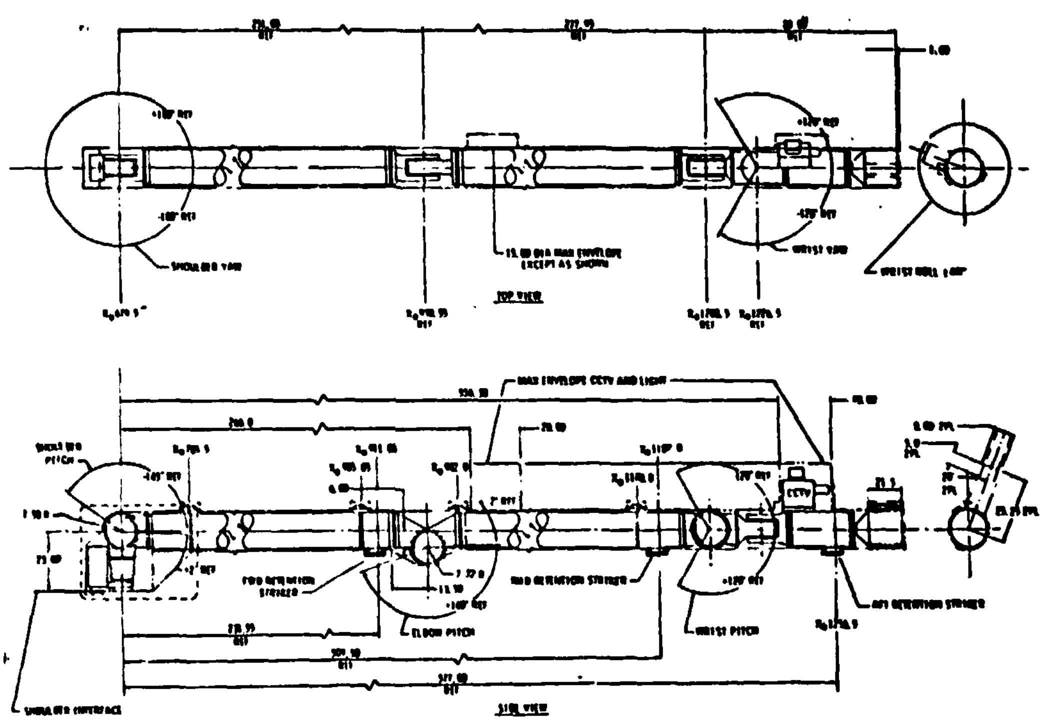


Figure 2.4-1 RMS Arm Dimensions and Joint Angle Limits

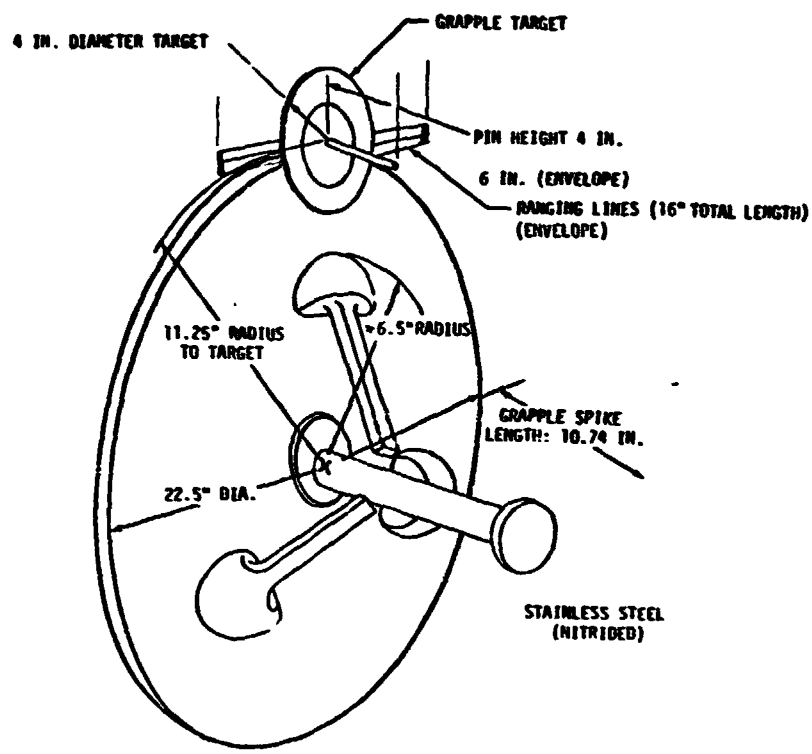


Figure 2.4-2 Standard Grapple Fixture and Target

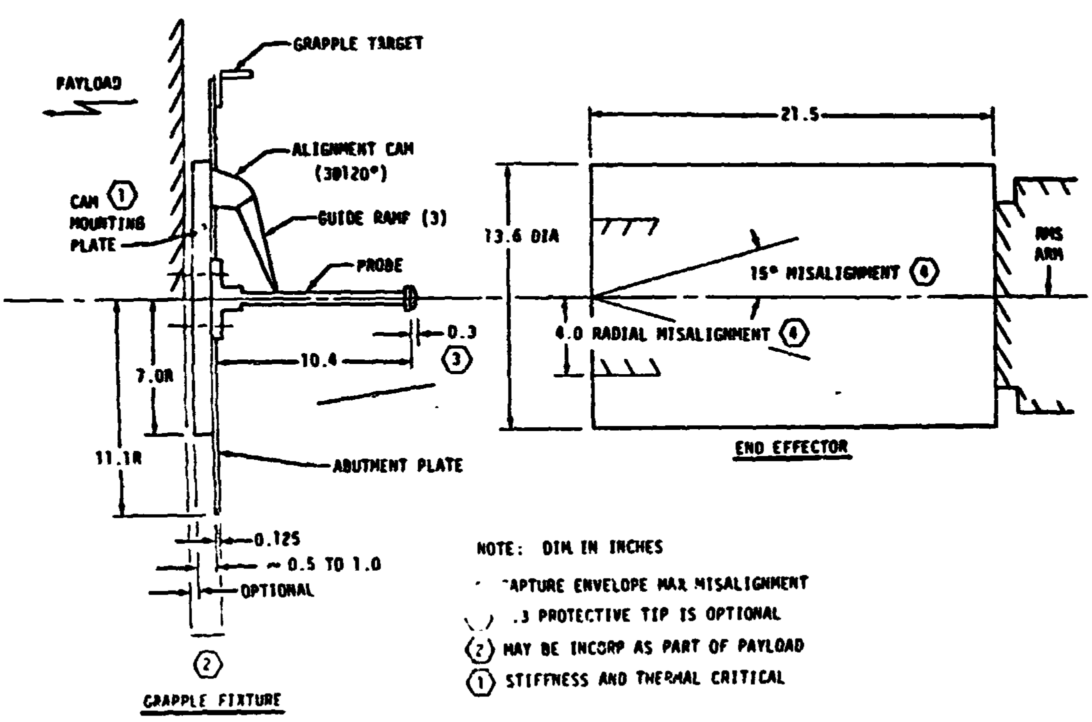


Figure 2.4-3 RMS Standard End Effector and Grapple Fixture Envelope Schematic

2.5 TDRSS

The SASP command and data management system must be compatible with the Tracking and Data Relay Satellite System (TDRSS), which provides the communication channel between the SASP/Power System and the ground. Certain interface parameters, such as EIRP, operating frequencies, and signal design are of concern primarily to the Power System rather than the Platform. TDRSS data rate limits and loading and scheduling factors, however, are important to the SASP data system design.

The data rate limits for the various TDRSS channels are as follows:

	Forward Link	Return Link
MA Channel	10 Kbps	50 Kbps
SSA Channel	300 Kbps	12 Mbps
KSA Channel	25 Mbps	300 Mbps

These limits define the maximum rates that data can be transmitted between the SASP/Power System and the ground. Data that must be acquired at higher rates require on-board buffering. The rate limits, coupled with the channel availability, determine the total quantity of data that can be transferred.

The TDRSS provides a large improvement over a ground-based network in the amount of coverage available to satellites in low earth orbit. Two TDR satellites provide an average of 88% coverage or better. However, a user's access to TDRSS resources depends on the overall loading on TDRSS by all users. Preliminary studies have indicated that in the 1985-1990 time frame the TDRSS will be heavily loaded. This implies that a SASP should have a data system that can dump data into the TDRSS at high rates so that TDRSS timeline can be used effectively.

2.6 VIEWING

One of the most attractive features of the platform concept is its ability to host a variety of viewing payloads. MDAC has attempted to maximize this potential by configuring the Platform to be responsive to viewing requirements. Viewing requirements both as specifies - integration time or viewing direction - or aggregates - simultaneous multidirection viewing or simultaneous single direction viewing - drive the platform design. The conclusions derived from the viewing analysis are: (1) that the Platform is a viable option for viewing experiments; and (2) that the synergistic benefits of multiple viewing payloads identified by T'.W can be achieved.

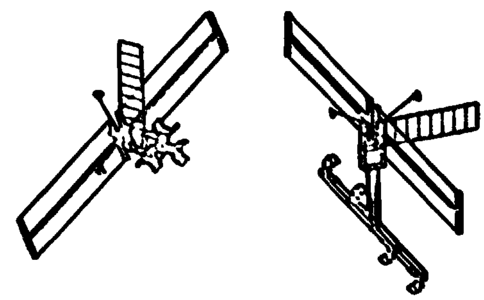
Figure 2.6-1 presents an overview of this analysis indicating its scope and the important conclusions and recommendations. MDAC employed two company developed computer tools in accomplishing these tasks. An interactive graphics program that simulates rotation of the platform elements and emulates sensor FOV's was used in determining obscuration. (Figure 2.6-2 illustrates its ability to examine a configuration from different viewpoints and with various focal lengths.) At a higher level, an experiment observation program was evaluated on an experiment effectiveness program that simulates the viewing performance over the complete mission. This computer program allows an experiment mounted on the Platform to be compared with the same experiment flown on dedicated spacecraft in terms of time to complete a specific set of experiment observations.

2.6.1 Viewing Requirements

Viewing requirements are divided into two classes: Those that are defined for individual experiments and those that result when more than one viewing experiment is on the Platform at the same time. In Figure 2.6.1-1 the instrument

REQUIREMENTS
- Directions
- Multi-Payload
- FOV and Integration Time
- TRW Defined Missions

TOPICS ADDRESSED
- On Orbit Capability
- Mini-Arm Trades
- Size Sensitivity
- Experiment Program Evaluation
- Prospects from: TBAR, Trail Arm, Second Order, First Order and Power System
- Mission Accommodation



CONCLUSIONS
- Second Order Platform Provides Simultaneous Multi-PLD, Multi-Directional Viewing
- First Order Platform Provides 3-Direction Simultaneous Viewing With Some Constraints

Figure 2.6-1 Viewing Summary

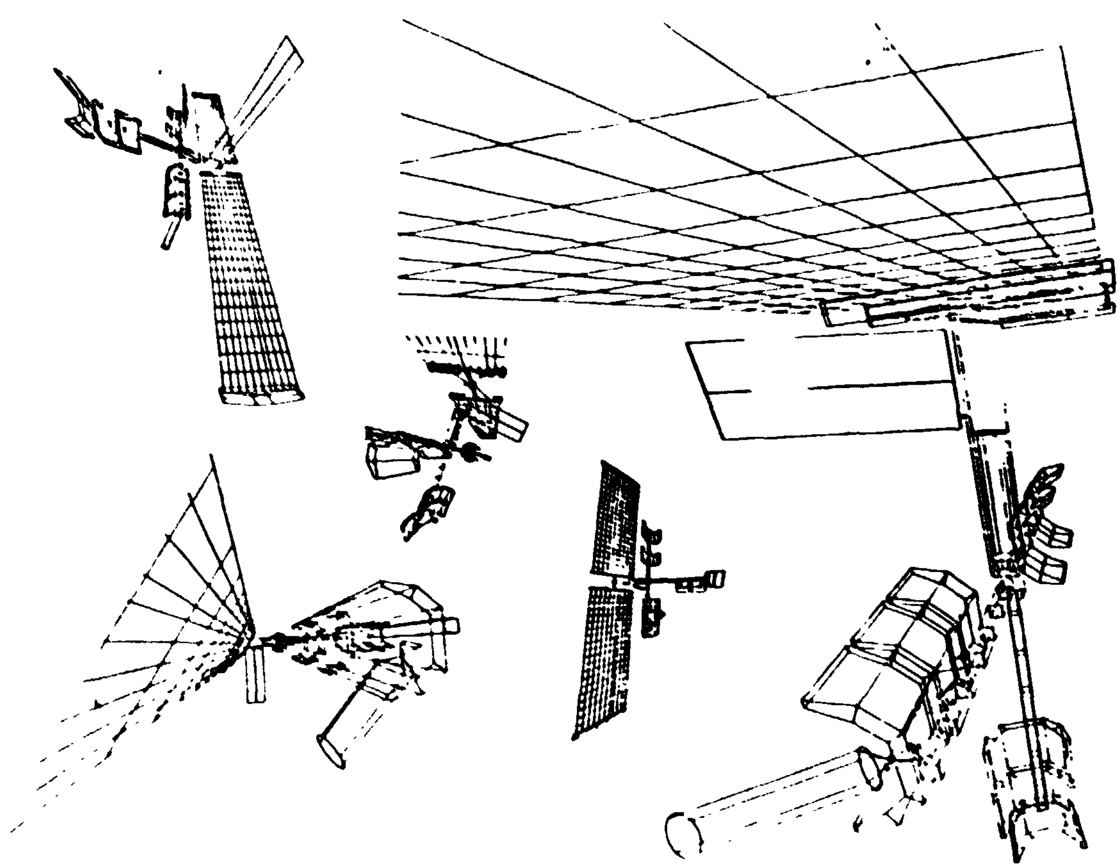


Figure 2.6-2 Computer Graphics for Platform Viewing Analysis

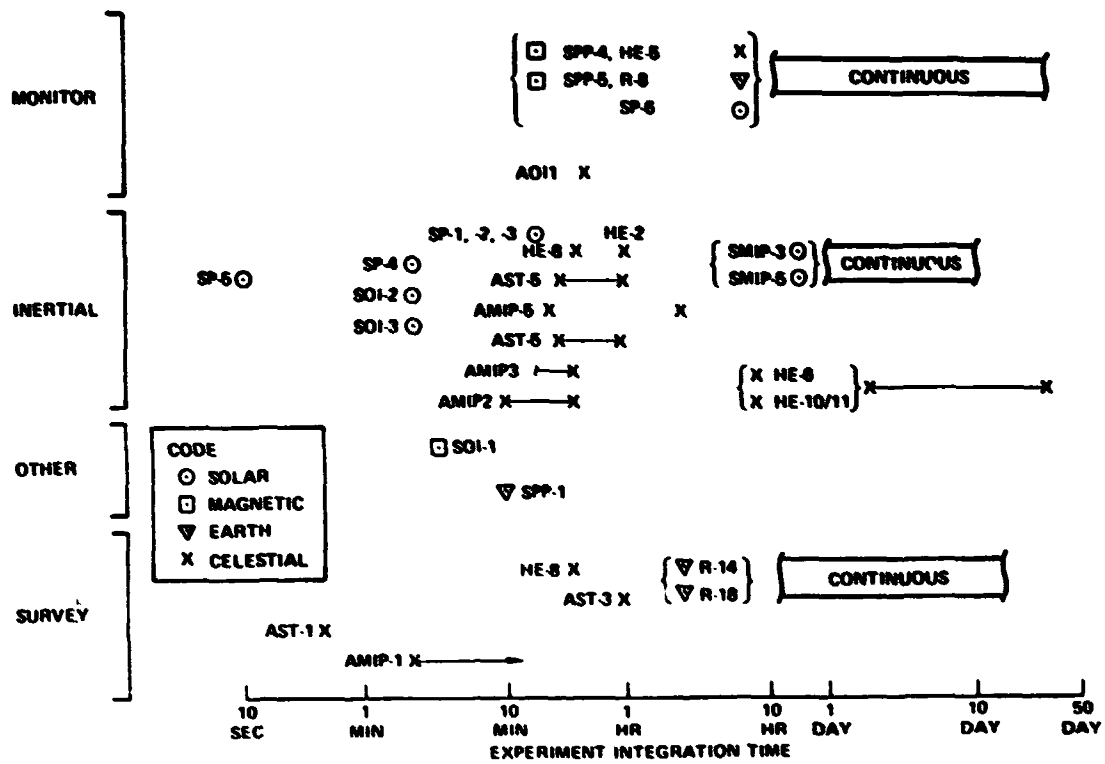


Figure 2.6.1-1 Integration Time Requirements

integration time (the time an instrument needs to perform a single observation of exposure) required is shown for several classes of viewing experiments. These times range from very short (seconds) to very long (days). An examination of the experiment yields the following list of viewing directions: earth, anti-earth, solar, celestial, magnetic line, and earth limb. Both sets of requirements are directly traceable to specific experiments and are of the first type mentioned above. When multiple viewing experiments are flown on a Platform new requirements result. To achieve the realization of the Platform's potential some degree of simultaneity in experiment operations is needed. Full simultaneous operation of all payloads on the Platform will maxin .e the Platform's usefulness but only if the experiments do not interfere with each other. The derived requirement is therefore multiple

simultaneous viewing directions without mutual interference. Conversely it is desirable (as pointed out in the companion TRW study) to be able to dedicate a platform, for some period of time, to a single viewing direction. These two general requirements make up the second class of requirements defined above.

2.6.2 Impact on Configuration

The early platform concept, a T-Bar configuration, evolved as a result of the requirement for simultaneous multi-directional viewing. This baseline configuration was employed in an experiment-by-experiment examination of whether the basic viewing requirements could be achieved if the experiment were flown on the Platform by itself. For example, parametric data was generated showing the relationship between instrument integration time, target declination and orbit inclination (Figure 2.6.2-1). Analogous data have been generated for solar, earth, and magnetic experiments. Conclusions reached were that from a viewing standpoint all requirements could be fulfilled if only one experiment was on the Platform.

The next step was to evaluate the experienced viewing capability when grouped on the T-bar configuration. The MDAC interactive 3-D graphics capability was employed to investigate potential obscuration.

Figure 2.6.2-2 illustrates views from various pallet locations. The rotation of the trail arm (assuming 3-direction simultaneous viewing with the trail arm earth looking) once per orbit could present a problem if large instruments are mounted on it causing a "windshield wiper" effect on cross-arm experiments looking aft. Similarly, instruments on the cross arms and the cross arms themselves could obscure trail arm instruments during a portion of the orbit. An additional consideration is that for light sensitive instruments, like

IR telescopes, the obscuration is magnified by exclusion zones around light reflecting or radiative surfaces. For these reasons subsequent configurations with cross arms have excluded long trail arms.

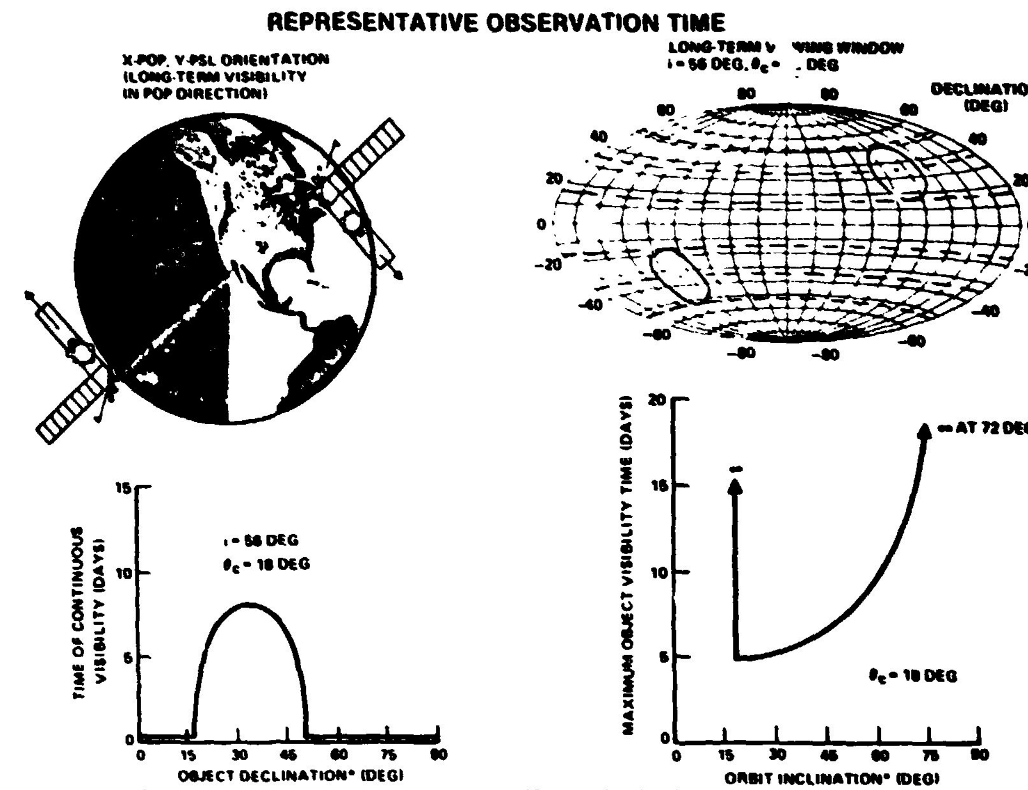


Figure 2.6.2-1 SASP Provides Long-Term Viewing Windows

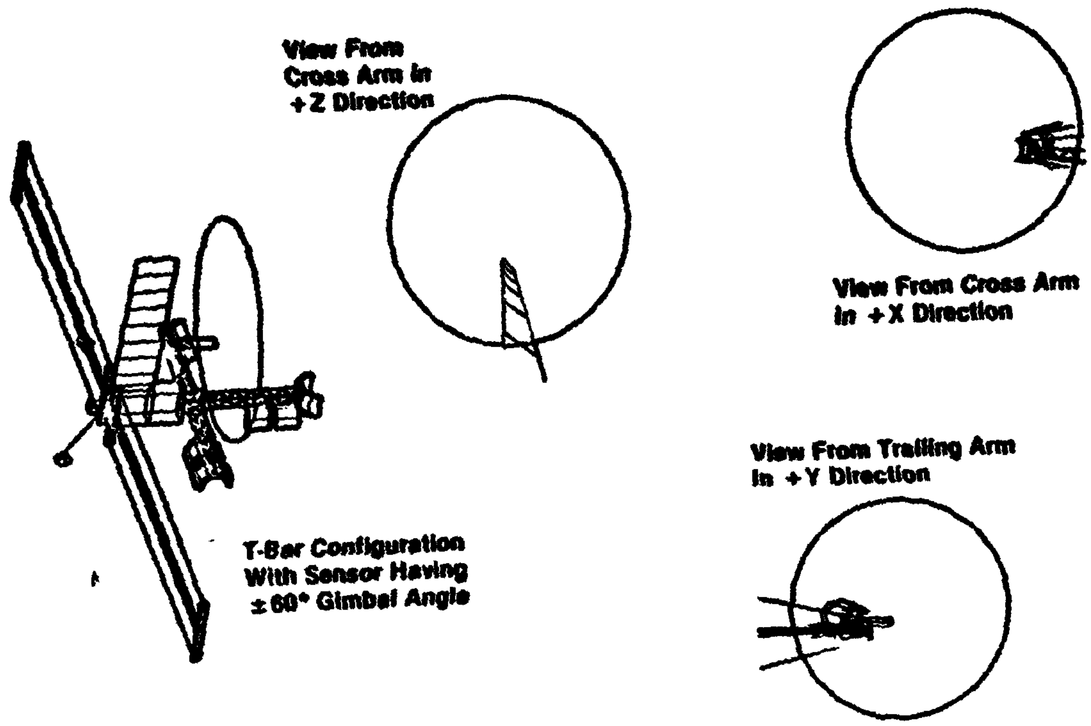


Figure 2.6.2-2 SASP T-Bar Visibility

The current 2nd order and extended 2nd order configurations have retained the best features of the T-Bar configuration and eliminated a significant amount of obscuration. In Figure 2.6.2-3 the viewing prospects from the extended 2nd order crossarms are presented. The cross-arm ports with large separation distances between berthing ports and independently rotating arms provides excellent viewing capability. Unobstructed visibility for effective 60° FOV instruments is obtained when either arm is rotated so the pallet is boresighted in the +X, +Z, and -Z directions. As shown, the solar panels obscure the view in the -X direction.

A sensitivity analysis was performed to determine the impact of platform size on viewing capability. One measure of platform size is the length of the standoff structure between the Power System and the SASP Support Module. Figure 2.6.2-4 displays the sensitivity of experiment viewing to this

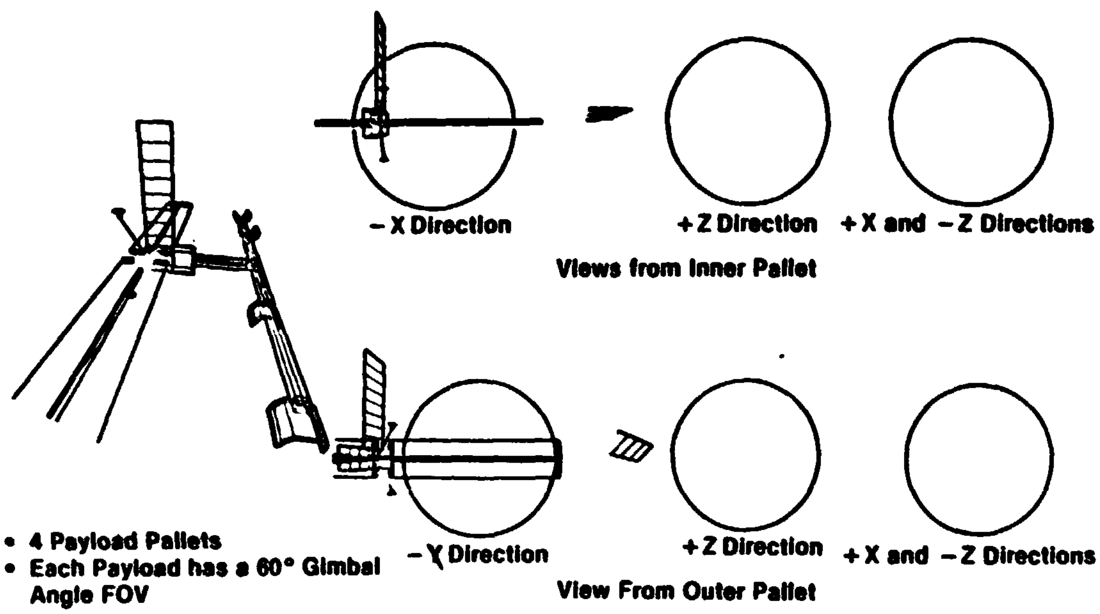


Figure 2.6.2-3 Second-Order Platform Visibility Cross Arm Configuration

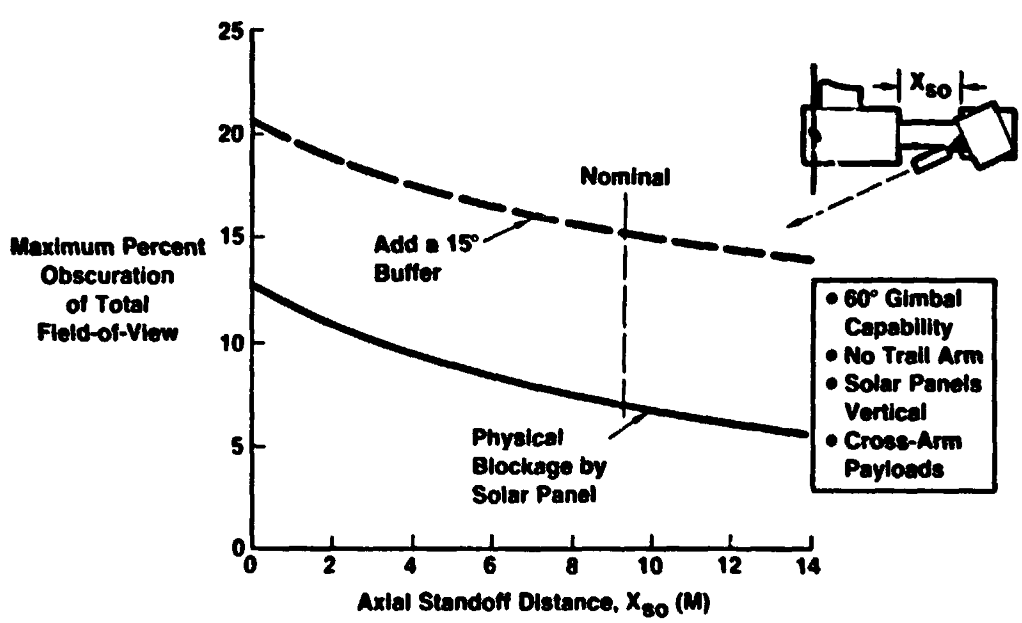


Figure 2.6.2-4 Experiment Viewing Sensitivity to Axial Standoff Distance

standoff structure length. Percent obscuration of the experiment field-of-view was selected as the viewing performance measure. Two conditions were examined; (1) obscuration caused by the solar panel alone, and (2) solar panel obscuration plus a 15° buffer to preclude reflected energy from reaching the experiment sensor. These curves indicate that viewing performance is relatively insensitive to this platform size parameter. A second measure of platform size is the distance from the platform centerline outboard to a berthing port. Using the same measure of viewing performance, percent obscuration at the total FOV, and obscuration parameters, the sensitivity to berthing port location is presented in Figure 2.6.2-5. Again, the conclusion drawn in viewing is a weak function of all platform size. However, other factors, such as allowable payload size, must be considered in determining experiment program sensitivity to platform size. (See Section 2.10.)

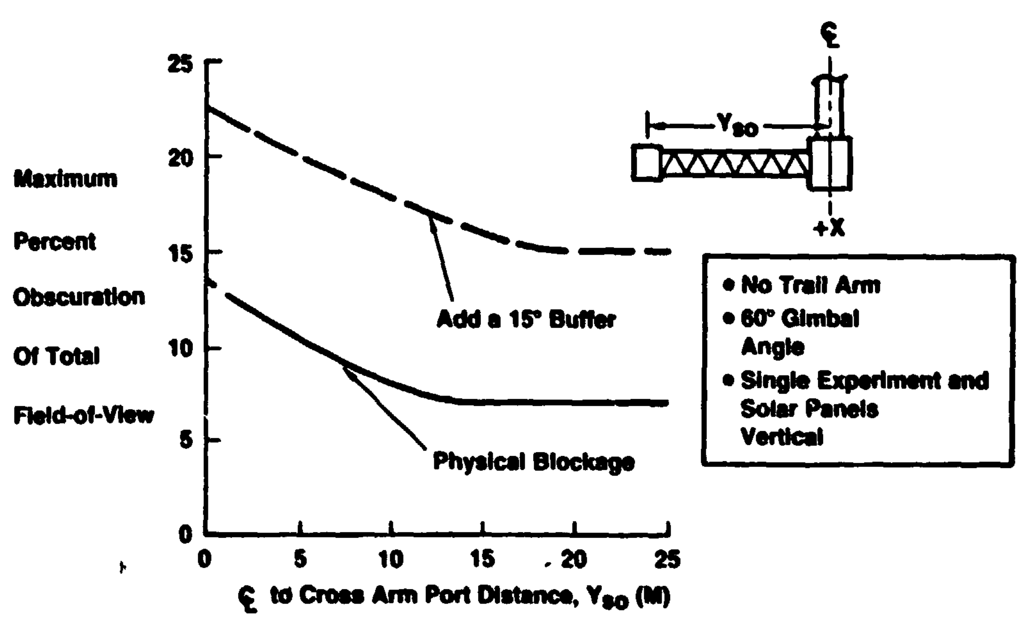


Figure 2.6.2-5 Experiment Viewing Sensitivity to Cross Arm Length

Viewing prospects from the 1st Order Platform are shown in Figure 2.6.2-6. Views from the opposite Y mini-arm are mirror images and views from the trail mini-arm are unobscured in both +X and -Z directions. Impact of viewing on the development of the 1st Order Platform is presented in Section 2.11.

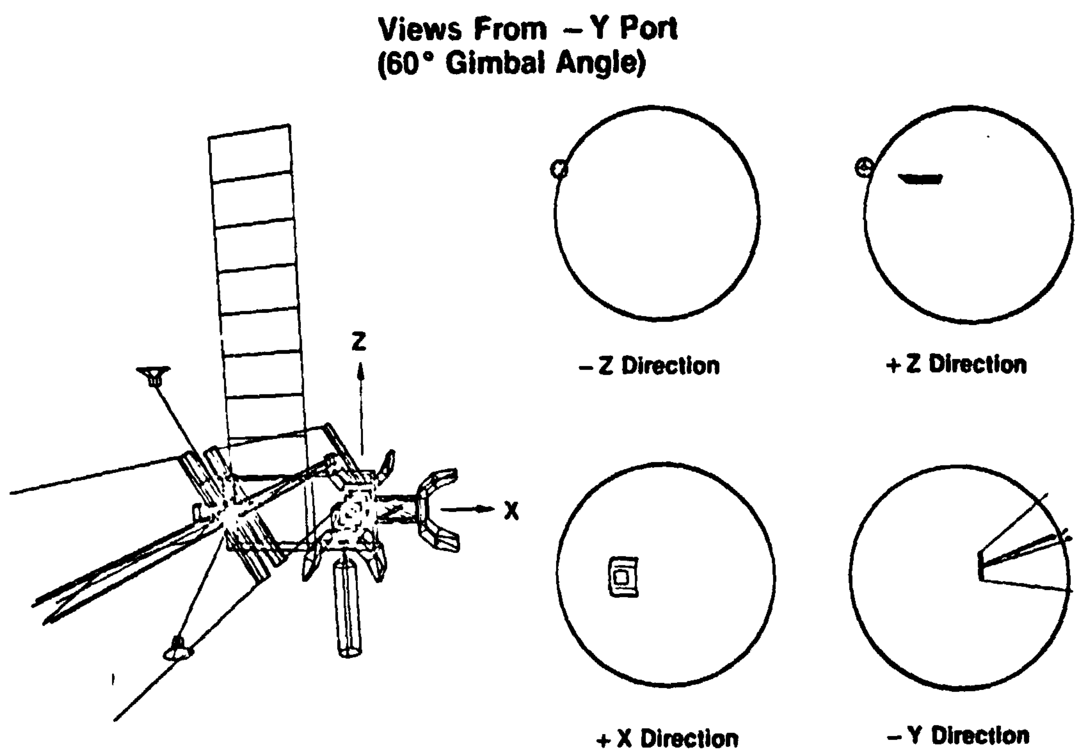


Figure 2.6.2-6 First-Order Platform Visibility

2.6.3 Viewing Comparison

MDAC has evaluated the ability of the SASP 1st and 2nd Order Platforms to support an experiment program. MSFC has defined an extensive astronomy viewing program that provided input to a MDAC developed experiment viewing simulation computing program. The minimum time for a dedicated spacecraft to complete this experiment program was determined and used as a measure of comparison.

The experiment program is defined in Figure 2.6.3-1. Forty-two target locations are defined with the time per observation, number of orbits per day with observations and consecutive days with observation or the total number of observations presented for each. Target locations are shown on the following chart (Figure 2.6.3-2), an Aitoff projection, showing the right ascension and declination of each.

Figure 2.6.3-3 presents a comparison of the time required to accomplish this experiment program between a dedicated spacecraft and the 2nd Order Platform. For the orbit selected and the assumption listed the SASP requires about 20% more time to carry out this program. The 1st Order SASP, without continuous arm rotation capability, is not competitive for this application.

The advantage that the on-orbit viewing direction change capability provided by the clocked arm/hinge has over a fixed arm is illustrated in Figure 2.6.3-4. A 50% increase in the number of experiments completed is gained by adding this on-orbit viewing direction change capability for the time required for a dedicated free flyer to complete the program.

TARGET PARAMETERS

NUMBER	RIGHT ASCENSION (DEG)	DECLINATION (DEG)	NUMBER OF CONSECUTIVE DAYS	ORBIT OBSER. FREQUENCY	MINUTES PER OBSERVATION
1	18.94	-73.71	16	1	10
2	135.06	-40.36	36	1	30
3	169.76	-60.35	9	1	10
4	234.66	-52.23	15	1	30
5	245.01	35.42	7	1	5
6	53.95	26.29	60	3	30
7	169.75	-61.59	60	3	30
8	176.39	-61.93	60	3	30
9	135.96	-62.49	120	16	30
10	189.78	-59.93	60	3	30
11	194.53	-61.33	60	3	30
12	246.81	-67.35	5	[illegible]	10
13	262.24	-24.71	30	3	30
14	58.06	30.90	6	1	25
15	82.88	21.98	3*	1	MAX
16	18.81	63.48	97	8	30
17	83.19	-66.40	11	1	20
18	[illegible]	-56.99	67	4	5
19	[illegible]	-40.75	30	3	30
20	[illegible]	-37.77	14	1	20
21	[illegible]3.74	49.35	6	1	30
22	229.12	35.07	17	3	20
23	307.66	[illegible].79	68	1	5
24	325.65	[illegible]	45	4	10
25	[illegible]8.12	-40.10			30
26	242.22	-52.30			30
27	244.23	-53.65	NO CONSECUTIVE REQUIREMENT. EACH TO BE OBSERVED ON A TOTAL OF 400 DISTINCT ORBITS.		30
28	254.73	-29.87			30
29	255.67	-42.97			30
30	262.[illegible]	-33.80			30
31	262.53	-33.35			30
32	263.83	-44.[illegible]			30
33	265.72	-29.50			30
34	265.61	[illegible]			30
35	265.37	-28.97			30
36	266.70	-37.04			30
37	275.12	-3[illegible].39			30
38	279.37	4.99			30
39	252.59	-8.77			30
40	286.48	0.09			30
41	299.04	-[illegible].33			30
42	321.89	11.95			30

*REPEAT SEQUENCE TWICE SEPARATED BY AT LEAST 90 DAYS.

Figure 2.6.3-1 Sample Viewing Experiment Program

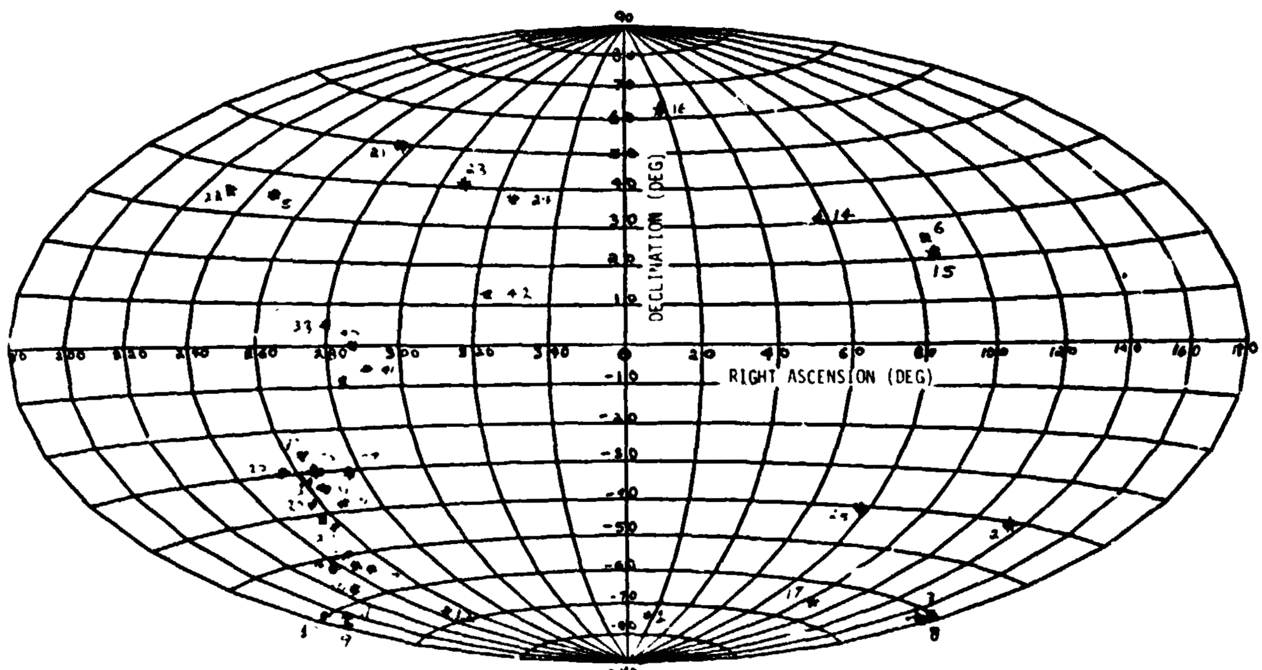


Figure 2.6.3-2 Target Locations

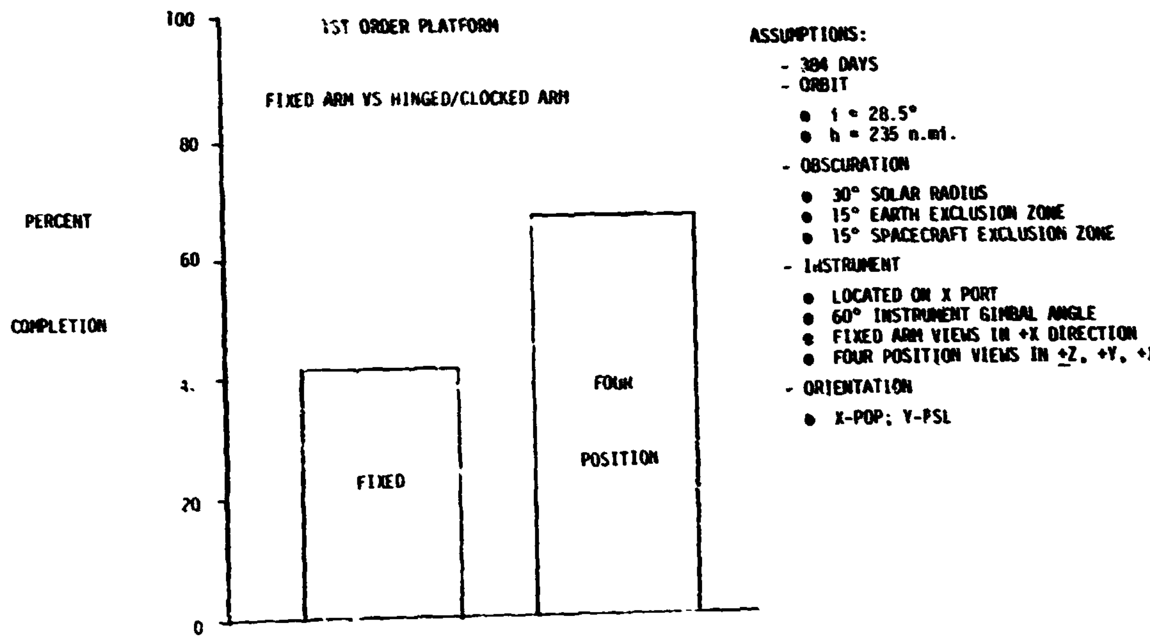


Figure 2.6.3-3 Performance Comparison
- Percent Viewing Experiment Program Completion -

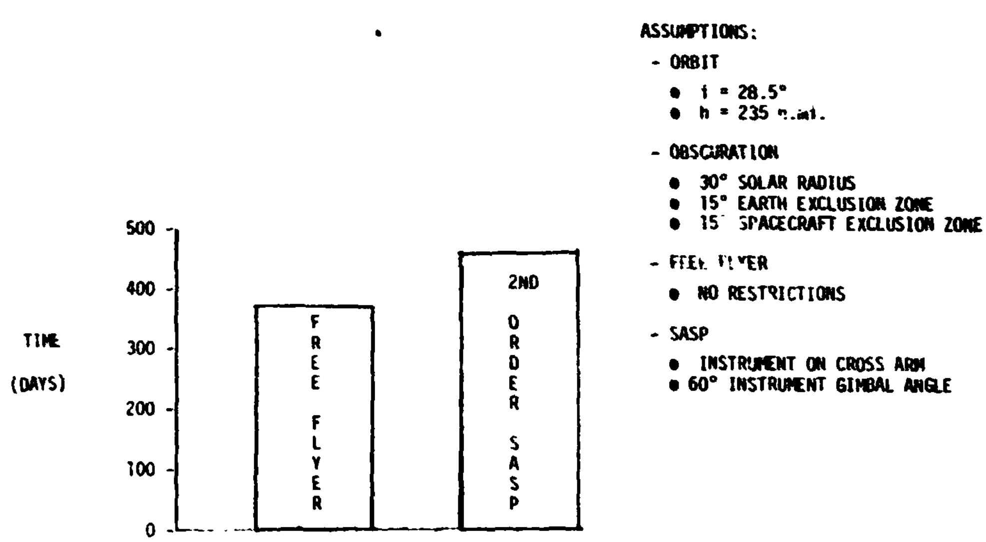


Figure 2.6.3-4 Performance Comparison
- Time to Complete Viewing Experiment Program -

2.7 DYNAMICS

Exℓeriment pointing requirements are collectively a major configuration driver. They impact both the ACS and the structural design. Figure 2.7-1 summarized the issues involved, the analyses performed, and conclusions and recommendations made. (This subject area which includes dynamics, structural dynamics, attitude control, and pointing systems is loosely defined here as dynamics.)

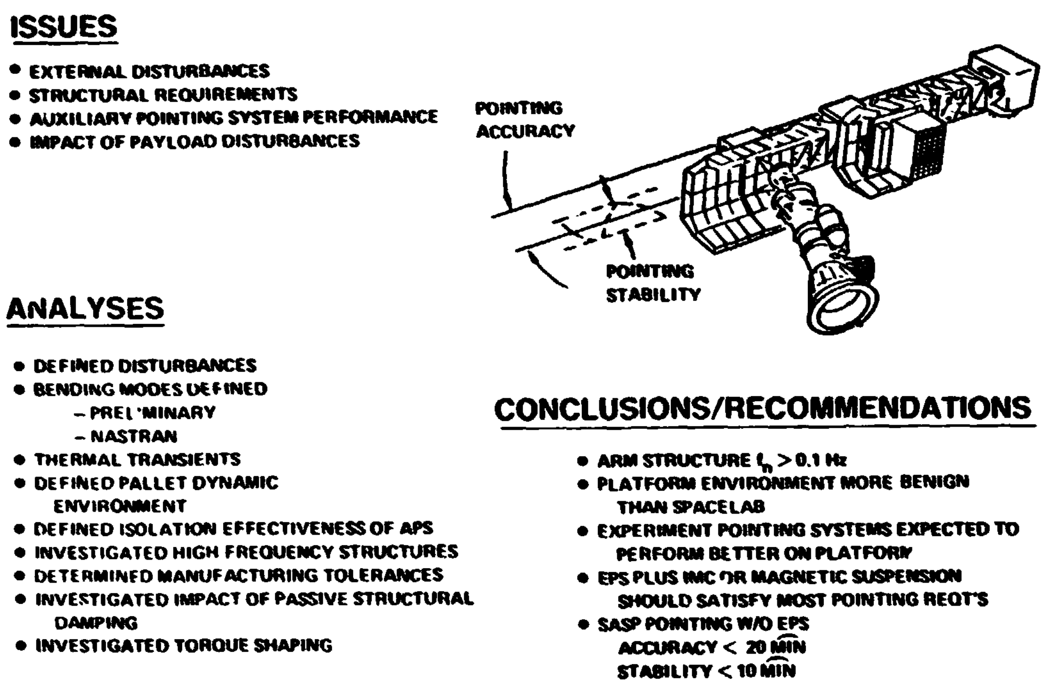


Figure 2.7-1 Dynamics

2.7.1 Requirements

The pointing requirements, pointing accuracy, and pointing stability were presented in Figure 2.1.5-1. Overlays on this chart indicate the performance capability of the IPS and the projected range of capability for the Platform. In order to meet these pointing requirements, either the platform capability must be greatly improved or the fine pointing capability must be allocated to

the payloads. For reasons of cost, complexity, and technology the fine pointing function has been allocated to the payloads.

2.7.2 Dynamic Environment at Pallet

Figure 2.7.2-1 defines the disturbances that must be neutralized to achieve the experiment pointing requirements. A computer program simulation was employed to quantify both gravity gradient and aerodynamic disturbances. Disturbances from other sources were evaluated and as a result experiment operations will be suspended when in the presence of the Orbiter and during PS thruster firing.

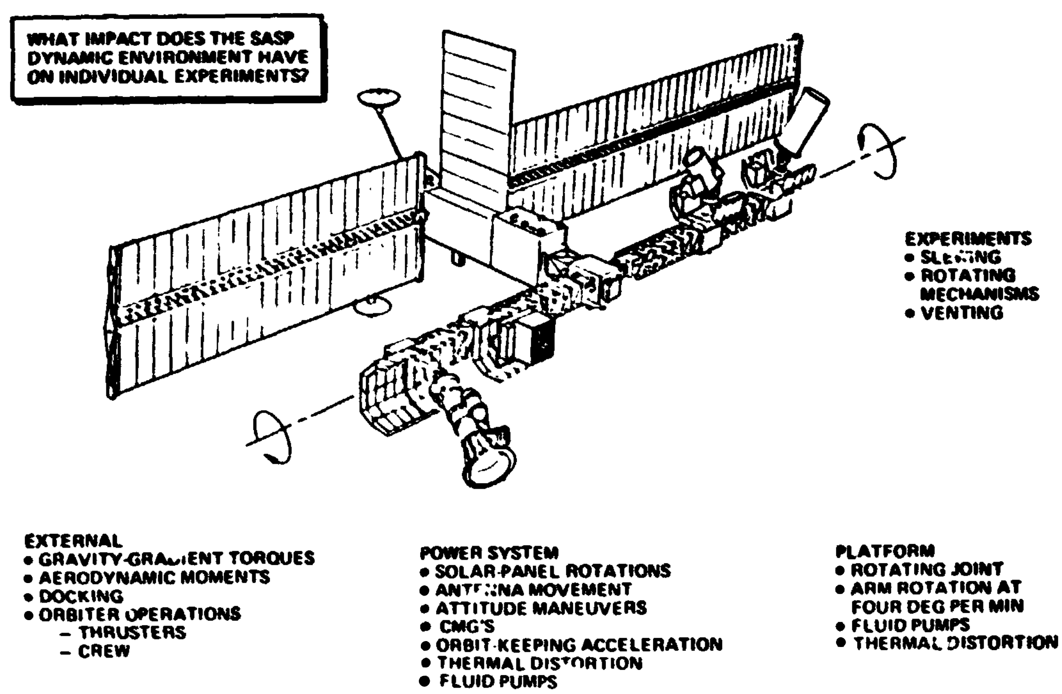


Figure 2.7.2-1 SASP Dynamic Environment

The largest disturbance identified excluding Orbiter and PS thrustor operations is the slewing of a payload instrument at the maximum ASPS gimbal moment of 34 N-M. Figure 2.7.2-2 shows a representative configuration that was modeled to evaluate the impact of this disturbance. (See ACS discussion in Section 4 for description of model.) Results of the analysis are presented in Figure 2.7.2-3. The MODE column defines the character of the mode shape with respect to where most of the motion occurs. For example, the RIGID BODY mode corresponds to a closed-loop control system mode and neither the solar array or Platform are bending significantly. The A through D columns define the rotation of the corresponding payload (A and C) or base of the auxiliary pointing system of the payload is used (B and D). ["Uncompensated" means without the benefit of an auxiliary pointing system.] The rotation results from a 34 N-M moment step input at payload D. The results indicate significant rigid body motion occurs (0.16 deg) which is characteristic of the 0.01 Hz controller bandwidth with no damping. Other rotations appear small with the exception of the second torsion mode which could be significant to some payloads with tight stability requirements. The modeling of the PS controller as a 0.01 Hz zero damped resonance is very conservative. Including realistic PS controller damping could reduce the 0.16 degree rigid body motion to about 0.1 degrees and the inclusion of the integral of attitude feedback in the PS controller may reduce the rigid body motion to 0.05 degrees or less.

2.7.3 Experiment Pointing System Contributions

Achievement of the fine pointing requirements is dependent on the capability of experiment pointing systems to isolate the experiment from the dynamic environment at the pallet. The Sperry Annular Suspension Pointing Gimbal System (AGS) was selected for this analysis because of availability of data. A computer model was developed to simulate the AGS. (Refer to AGS writeup in Section 4 for discussion.)

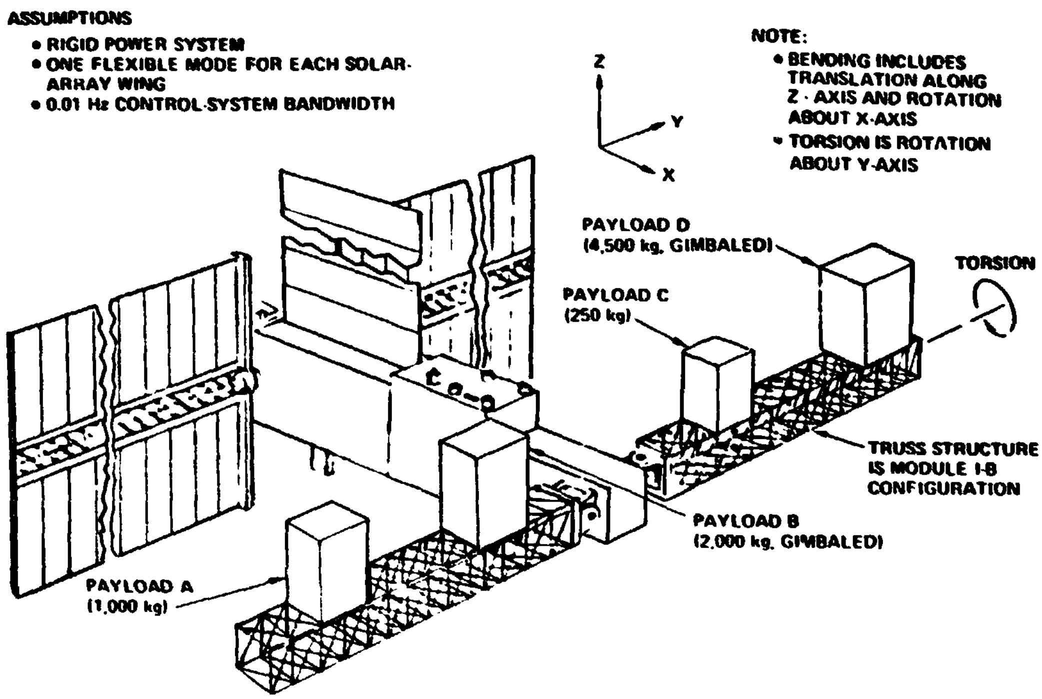


Figure 2.7.2-2 SASP Simplified Dynamics Analysis Model

MODE	FREQ (Hz)	ROTATION** (SEC) AT INDICATED PAYLOAD			
		A	B	C	D
RIGID BODY	0.01	586	586	586	586
1ST SOLAR ARRAY	0.054	0.0[illegible]	0.001	0.002	0.002
2ND SOLAR ARRAY	0.055	1.6	1.6	1.6	1.6
1ST BENDING	0.55	0.82	0.71	0.48	0.67
2ND BENDING	0.94	~0	~0	~0	~0
3RD BENDING	1.4	~0	~0	~0	~0
4TH BENDING	1.9	0.24	0.08	0.02	0.10
5TH BENDING	2.9	0.13	0.006	0.02	0.25
1ST TORSION	0.63	0.42	0.28	0.004	0.005
2ND TORSION	0.86	0.14	0.05	19	29
3RD TORSION	2.14	0.02	0.05	~0	~0
4TH TORSION	2.16	0.02	0.04	2.4	2.2

*MAXIMUM ANNULAR SUSPENSION POINTING SYSTEM (ASPS) GIMBAL MOMENT

**AUXILIARY POINTING SYSTEMS REDUCE ROTATIONS FOR EXPERIMENTS (COMPENSATED RESPONSE)

Figure 2.7.2-3 Uncompensated Response to 34 N-M* Moment Input at Payload D

The dynamic environment shown in Figure 2.7.2-3 was used to evaluate the ability of a pointing system to satisfy the fine pointing requirements. The linear acceleration values associated with each dynamic modal characteristic are shown on Figure 2.7.3-1 for the three payloads which are disturbed by a maximum AGS gimbal torque input at Payload D. The first column for each payload corresponds to linear acceleration due to SASP arm bending rotation or torsion rotation. This linear acceleration (due to rotation) is proportional to the distance from the SASP arm neutral axis and is shown as acceleration per meter from the neutral axis. A realistic value for this distance (ℓ) is three meters.

MODE	FREQUENCY (Hz)	PAYLOAD A $\ddot{Y}/\ell$ (10^{-6} G'S/m)	PAYLOAD A $\ddot{Z}$ (10^{-6} G'S)	PAYLOAD B $\ddot{Y}/\ell$ (10^{-6} G'S/m)	PAYLOAD B $\ddot{Z}$ (10^{-6} G'S)	PAYLOAD C $\ddot{Y}/\ell$ (10^{-6} G'S/m)	PAYLOAD C $\ddot{Z}$ (10^{-6} G'S) *
RIGID BODY	0.01	0.56	14	0.56	8.4	0.56	5.2
1ST SOLAR ARRAY	0.054	~ 0	0.012	~ 0	0.012	~ 0	0.013
2ND SOLAR ARRAY	0.055	0.046	1.1	0.046	0.72	0.046	0.39
1ST BENDING	0.55	2.4	29	2.1	7.2	1.4	4.2
2ND BENDING	0.94	~ 0	0.002	~ 0	0.004	~ 0	0.008
3RD BENDING	1.4	~ 0	0.012	~ 0	0.006	~ 0	0.004
4T. BENDING	1.9	8.2	33	2.8	31	0.69	26
5TH BENDING	2.9	10	25	0.49	43	1.6	130
1ST TORSION	0.63	1.6	–	1.1	–	0.016	–
2ND TORSION	0.86	1.0	–	0.36	–	140	–
3RD TORSION	2.14	0.89	–	2.2	–	~ 0	–
4TH TORSION	2.16	0.92	–	1.8	–	110	–

*MAXIMUM ANNULAR SUSPENSION POINTING SYSTEM (ASPS) GIMBAL MOMENT CAPABILITY

Figure 2.7.3-1 SASP Acceleration Response to 34 N-m* Payload D Gimbal Torque

The second column for each payload gives the linear acceleration associated with the linear translation associated with SASP arm bending.

The largest acceleration shown is 420 micro g's (assuming a three-meter ·) for Payload C and the second torsion mode. The largest "Z" is 130 micro g's for Payload C and the fifth bending mode. These accelerations would be unacceptable to a materials processing payload (10^{-5} g requirement) and indicate that some operational torque constraints will be required when operating in low-g flight mode. This corroborates the rigid body disturbance acceleration analysis discussed previously.

These accelerations, when applied perpendicular to the auxiliary pointing system line-of-sight (LOS), result in dynamic payload LOS errors (see Figure 2.7.3-2). The LOS errors resulting from a maximum AGS torque step of Payload D are shown on Figure 2.7.3-3. The first column for each payload is normalized with respect to distance ( ) from the SASP arm neutral axis. A typical value for is three meters; the values in the first column for each payload can be multiplied by three to obtain realistic LOS errors.

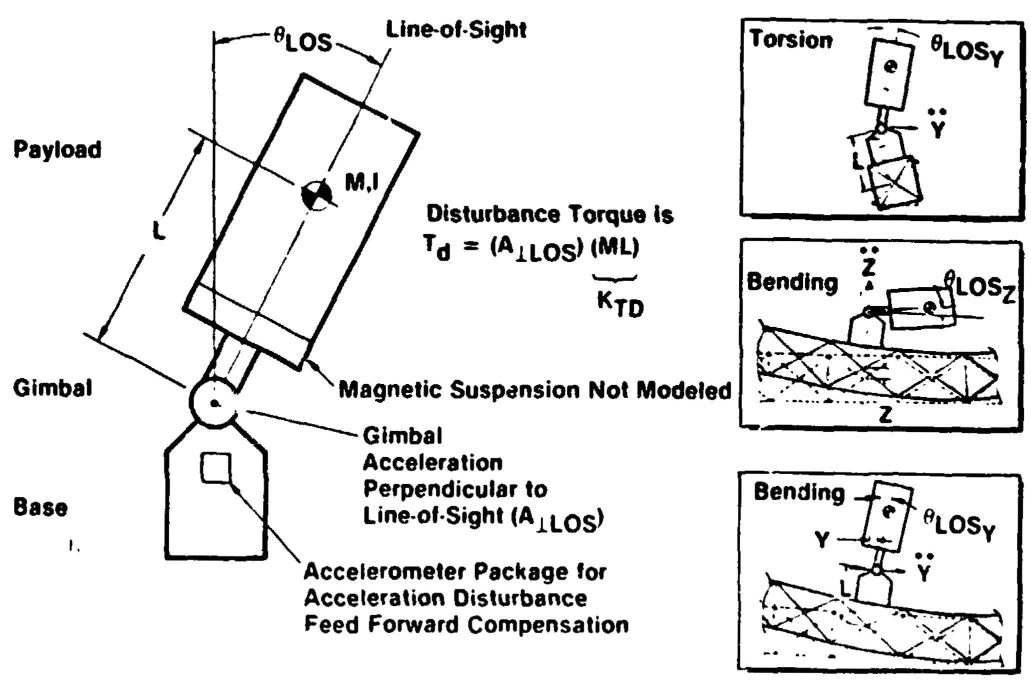


Figure 2.7.3-2 Pointing System Acceleration Disturbance Model

MODE	FREQ (Hz)	PAYLOAD A θ_{LOS_Y}/ℓ (ARC SEC/m)	PAYLOAD A θ_{LOS_Z} (ARC SEC)	PAYLOAD B θ_{LOS_Y}/ℓ (ARC SEC/m)	PAYLOAD B θ_{LOS_Z} (ARC SEC)	PAYLOAD C θ_{LOS_Y}/ℓ (ARC SEC/m)	PAYLOAD C θ_{LOS_Z} (ARC SEC)
RIGID BODY	0.01	1×10^{-5}	3×10^{-4}	1×10^{-5}	2×10^{-4}	1×10^{-5}	1×10^{-4}
1ST SOLAR ARRAY	0.054	~ 0	2×10^{-6}	~ 0	2×10^{-6}	~ 0	2×10^{-6}
2ND SOLAR ARRAY	0.055	6×10^{-6}	1×10^{-4}	6×10^{-6}	1×10^{-4}	6×10^{-6}	5×10^{-6}
1ST BENDING	0.58	1×10^{-3}	0.012	9×10^{-4}	3×10^{-3}	6×10^{-4}	2×10^{-3}
2ND BENDING	0.94	~ 0	7×10^{-7}	~ 0	1×10^{-6}	~ 0	3×10^{-6}
3RD BENDING	1.4	~ 0	3×10^{-6}	~ 0	2×10^{-6}	~ 0	1×10^{-6}
4TH BENDING	1.9	2×10^{-3}	7×10^{-3}	6×10^{-4}	7×10^{-3}	1×10^{-4}	5×10^{-3}
5TH BENDING	2.9	2×10^{-3}	4×10^{-3}	8×10^{-5}	7×10^{-3}	3×10^{-4}	$\boxed{0.020}$
1ST TORSION	0.63	7×10^{-4}	–	5×10^{-4}	–	6×10^{-6}	–
2ND TORSION	0.86	4×10^{-4}	–	1×10^{-4}	–	$\boxed{0.049}$	–
3RD TORSION	2.14	2×10^{-4}	–	4×10^{-4}	–	~ 0	–
4TH TORSION	2.16	2×10^{-4}	–	4×10^{-4}	–	$\boxed{0.021}$	–

*ANNULAR SUSPENSION POINTING SYSTEM GIMBAL SYSTEM
**MAXIMUM AGS TORQUING CAPABILITY
NOTES: SIRTF PAY OAD WITH FIVE PERCENT MASS PROPERTIES PREDICTION ERROR ASSUMED

Figure 2.7.3-3 AGS* LOS Disturbances Due to a 34 N-m** Payload D Torque (0.15 Arc Sec)

Note the LOS error units are arc-sec and the tightest payload pointing stability requirements is 5 X 10^{-3} arc-sec (AOI-2, Figure ACS-1). Another point of interest is that the quiescent capability of the ASPS is 10^{-2} arc-sec. Therefore, most of the values on this chart are well below experiment requirements or below the "noise level" of the auxiliary pointing systems.

Some exceptions exist, however. The LOS error for payload C and second torsion mode is 0.15 arc-sec (assuming ℓ = three meters). Also, the fourth torsion mode and fifth bending mode result in LOS errors which are above the AGS "noise". (The accuracy of these higher frequency modes is questionable because of the simplified flexible dynamic model used.)

The results shown here indicate that the inter-payload slewing disturbances will be acceptable to most pointing payloads. A few payloads with the most

severe performance requirements may impose some slewing restrictions on other payloads. Internal instrument motion compensation systems may be required to compensate for other payload slewing disturbances.

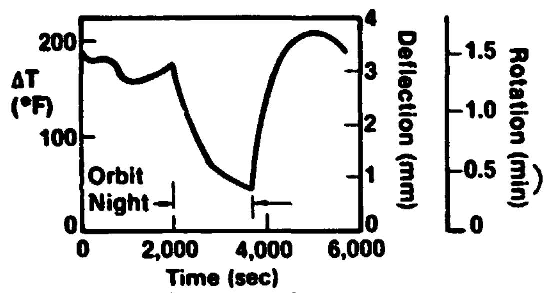
Current IPS performance with the Orbiter indicates potential problems in the SASP environment. SASP bending modal frequencies are lower than the Orbiter frequencies and can fall within the IPS controller bandwidth which may cause IPS control stability problems. MDAC briefly investigated a 4 Hz structure raising the structure frequency above that of the IPS. However, the SASP dynamic environment is expected to be much more benign than that of the Orbiter and the stability problems, if real, solvable by software modifications.

2.7.4 Thermal Distortions

Structural deformations resulting from thermal gradients in the truss structure were analyzed. The analysis assumed a graphite/epoxy structure. A factor of about 100 should be applied to increase the thermally induced motions for an oncoated aluminum structure. The thermal transients associated with day/night-night/day transitions can drive flexible body dynamics.

Figure 2.7.4-1 defines the differential temperature (ΔT) across the SASP arm for an orbit. Assuming the thermal deformation to be proportional to ΔT, the deflection and rotation of the end of an arm is shown. The conditions are noted to the right of the graph. The transitions from orbit-day to orbit-night and the opposite generate the fastest changing thermal characteristics with the most potential to disturb payloads. Transition from orbit-day-to-night is the worst case since the SASP radiated power-input power differential is maximum. As shown the thermal deformation is relatively small and can easily be isolated by an auxiliary pointing system.

SASP Strut Differential Temperature Effects Example



Thermo Generated G-Levels

- Transition From Orbit-Day to Orbit-Night
- First Bending Mode Excitation Results in Maximum of 10^{-6} G's at 0.5 Hz
- AGS Pointing System Pointing Disturbance Less Than 0.01 sec Due to Thermal Distortion

- Rotation and Deflection at Outer End of SASP Cross Arm
- 435-km Altitude
- β Angle of 52°
- Graphite/Epoxy Str[illegible]
- Pallet/SASP Tilted 40° to Sun Line

- Auxiliary Pointing Systems Can Isolate Payloads from Thermal Deformations
- Materials Processing Experiments Are Not Impacted by Thermal Deformation Transients

Figure 2.7.4-1 Thermal Deformation Dynamics

2.7.5 NASTRAN Model and Structural Damping

The detailed NASTRAN model identified the first crossarm bending mode occuring at about 0.2 Hz. This is somewhat lower than the 0.55 Hz mode used in defining the dynamic environment. However, this small difference in frequency should not significantly influence the conclusions reached.

Results of the NASTRAN analysis were employed to identify the impact of structural damping. Potential improvements were identified for even low levels of damping. Refer to the structures section for the NASTRAN model definition, the mode shapes and the damping discussion.

2.7.6 Torque Shaping

As previously identified, the largest contributor to pointing errors during the experiment operations, is AGS torque from slewing payloads. These will

be limited by constraining the magnitudes and shaping the torque histories to minimize the induced structural responses. Similar constraints should also be applied to the PS ACS to limit its contribution. See the ACS discussion in Section 4 for further details.

2.7.7 Pointing Error Budget

The pointing errors shown on Figure 2.7.7-1 are components of the total pointing error to the payload. The joint indexing error of 0.2 deg was chosen to be similar to the best capability of the Reference PS (0.3 deg) to provide a balance in the PS and SASP error contributors. However, since the PS error can reach two deg in the worst case, the PS dominates the worst accuracy number. The PS error can be measured and available to the payload by using payload-provided sensors or sensors mounted directly to the SASP. This latter option is not currently part of the SASP but may be desirable, especially if none of the pointing payloads on a particular SASP have sensors suitable for attitude determination (e.g., earth mapping instruments). The SASP error sources were added (rather than RSS'd) since they can all add at certain flight times. The pallet thermal errors are TBD but cursory analysis indicates that deformations can be large compared to a graphite/epoxy SASP.

The Reference PS contributions are the largest errors. This is partly due to the aluminum structure and partly to lack of data. The Power System 5 arc-min stability value results from the previously described dynamic response (rigid body) to a full-on AGS gimbal torquer but with controller damping included.

The flexibility value (0.5 arc-min) also comes from the dynamic response analysis and corresponds to the second torsion mode motion at Payload D.

Error Source	No Auxiliary Pointing System	
	Accuracy (± arc min)	Stability (± arc min)
SASP*		
Free Play	1.38 — 1.77	1.38 — 1.77
Mfg and Assembly	2 — 2.25	—
Thermal	0.38 — 1.28	0.38 — 1.28
Rotational Joint Indexing	0** or 12	0** or 6†
	3.8 — 17.3 sum	1.8 — 9.1 sum
PALLET		
Mounting	0.41 — 1.32	—
Thermal	TBD	TBD
POWER SYSTEM	18 — 120 [Ref. Power System]	1 — 5***
FLEXIBILITY (DYNAMICS)		
34 N-m Pointing System Gimbal Torque	—	0.5
	18.4 — 121 RSS	2.1 — 10.4 RSS
IMPROVEMENTS		
With Payload Sensor Feedback	20	2.1-10.4 RSS
With APS	APS Accuracy	0.15 Arc Sec

†Can Be Made Essentially Zero
*Outer End of Arm, Concept B
**Perpendicular to Joint Axis
***34 N-m Pointing System Torque

Figure 2.7.7-1 SASP Pointing Error Budget

The RSS results show that the PS dominates the accuracy errors and SASP dominates the stability errors. The rotary joint servo could be designed such that it was very stable (e.g., no back drive) which would reduce the six arc-min value to essentially zero. Auxiliary pointing systems (APS) can improve the pointing performance significantly. The 0.15 arc-sec stability value is based on Figure ACS-15 and a 3 m lever arm. The 121 arc-min accuracy value should be acceptable with the utilization of auxiliary pointing systems as long as their target acquisition volume (solid angle) is greater than 121 arc-min. Some non-gimballed payloads may require a better accuracy and inclusion of additional sensors on SASP.

2.7.8 Summary

Current analysis results on IPS indicate control system stability problems exist for pointing systems. The NASTRAN modal analysis of a SASP configuration (documented herein) shows many frequencies below the 1 Hz which has been mentioned as a bandwidth goal for the IPS and AGS. Thus, potential stability problems must be a consideration. The expectation that the SASP disturbance environment is much less severe than on Orbiter leads to the conclusion that SASP pointing system bandwidths can be reduced which should help alleviate the problem. Designed-in structural damping currently appears to be feasible and will relieve the stability problem. Modifications and improvement to pointing system design also could prove beneficial.

Simultaneous operation of more than one pointing system could lead to composite control system stability problems or performance degradation. The pointing systems couple in a closed-loop manner through the structure. An executive control system concept is a potential solution.

The SASP disturbances can be further reduced relative to the Orbiter disturbances by limiting the pointing system torque magnitudes and shaping the torque histories to minimize the induced structural flight responses.

The dynamics effort to date has considered only "open-loop" APS responses to SASP motions. Further work is needed to determine the "closed-loop" AGS LOS responses to various disturbances . A subject of interest is the optimization of the torque command history for a given maneuver to minimize the excitation of the flexible modes. The simultaneous operation of more than one pointing system should be analyzed. The basic stability of the combined system may be impacted as well as the pointing system performance.

More detail definitions of vehicle orientation requirements are needed with realistic operational scenarios so that attitude control system sizing can be firmed up. Accuracy constraints on orientations are needed along with orientation hold duration requirements.

In order to preclude PS attitude control system stability problems a preliminary requirement was imposed on the SASP structure that stated there be an order of magnitude frequency separation between the ACS and the largest structural bending mode $-f_n > 0.1$ Hz. The resultant structural designs all met this requirement.

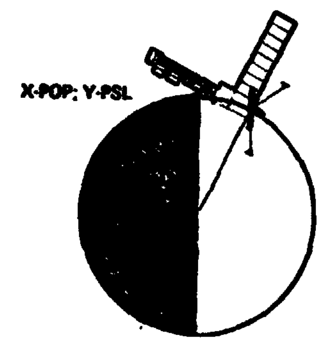
2.8 ORIENTATION

Platform on-orbit orientation and configuration design are interdependent. Given a design the orientation selection(s) is driven by that design and vice versa. A flexible approach to orientation has been adopted to minimize platform complexity and preclude sophisticated hardware design solutions that might result from adopting a single orientation.

Figure 2.8-1 enumerates the factors that impact orientation selection. The evolutionary SASP configuration growth when combined with the variety of experiment viewing directions and the desire to fly different mixes of experiments on separate missions lead to flexible posture where orientation is both selectable and changeable maximizing responsiveness to mission/experiment requirements. A shopping list of orientations (not exhaustive) is presented in Figure 2.8-2 with some recommendations for a variety of missions and configurations. Singling out an example; the dedicated earth viewing mission on the 1st Order Platform might have three earth pointing payloads operating simultaneously each on a separate mini-arm. In the recommended Z-LV orientation (radiator pointed toward the Zenith) each of the payloads is

DRIVERS

- **Configuration**
  - **First-Order Platform**
  - **T-Bar Viewing**
  - **Cross-Arm Platform Viewing**
  - **Trail-Arm Platform Viewing**
- **Experiment View Directions**
  - **Solar**
  - **Earth**
  - **Magnetic Lines**
  - **Atmosphere**
  - **Celestial**
  - **Anti-Earth**
  - **Inertial**



- **Mission**
  - **Dedicated to One Direction**
  - **Two Directions**
    - **Simultaneous**
    - **Sequential**
  - **Three Directions**
    - **Simultaneous**
    - **Sequential**
  - **Combo Sortie**

APPROACH

- **Adopt a Flexible Posture**
  - **Changed by Mission Controllers**
  - **Respond to Unique Experiment Needs**
  - **Exploit Full Capabilities of Power System**
    - **Excess Power**
    - **CMG Desaturation Variation**
- **Many Orientations Feasible**

Figure 2.8-1 SASP Orientation Driven By Mission Requirements

CANDIDATES

- X-POP; Y-PSL
- Z-POP; Y-PSL
- Z-LV {X-POP / Y-POP}
- X-LV {Z-POP / Y-POP}
- Z-LV; Y-PSL
- X-LV; Y-PSL

- SHORT TIME ANY ARBITARY ORIENTATION

RECOMMENDATIONS

MISSIONS	FIRST ORDER PLATFORM	T-BAR	CROSS-ARM
SOLAR DEDICATED	{X-LV; Z-POP / Z-LV; Y-POP}	{X-LV; Z-POP / Z-LV; Y-POP}	X-POP; Y-PSL; Z-IOP
EARTH DEDICATED	Z-LV {X-POP / Y-POP}	Z-LV {X-POP / Y-POP}	Z-LV {X-POP / Y-POP}
CELESTIAL DEDICATED	X-POP; Y-PSL	Z-POP; Y-PSL	Z-POP; Y-PSL
SOLAR – EARTH	Z-LV {X-POP / Y-POP}	X-POP; Y-PSL	Z-LV {X-POP / Y-POP}
CELESTIAL – EARTH	Z-LV {X-POP / Y-POP}	X-POP; Y-PSL	Z-LV {X-POP / Y-POP}
SOLAR – CELESTIAL	Z-POP; Y-PSL	X-POP; Y-PSL	Z-POP; Y-PSL
SOLAR – CELESTIAL – EARTH	{X-LV; Z-POP / Z-LV; Y-POP}	X-POP; Y-PSL	SEQUENTIAL

Figure 2.8-2 SASP Orientation Options

C-2

pointed in the -Z direction (toward the nadir) fulfilling the directional experiment requirements.

Achieving maximum flexibility in orientation selection does not however come free. Figure 2.8-3 shows the impact of Beta Angle (angle between the orbit plane and solar vector) on electrical power available to SASP. The X-POP, Y-PSL orientation can provide the full power potential. For a Z-LV, Y-POP orientation power varies from the full potential at zero Beta to zero power at 90°. Conversely, power varies from the full potential at 90° to around 8 kW at zero Beta for the Z-LV, X-POP orientation. Combining these Z-LV orientations by rotating from Y-POP to X-POP as Beta increases from low to high values provides a minimum of 22 kW. Thermal dissipation evidences similar trends. (One as yet unmentioned orientation presents an interesting potential that should be further explored. A Z-LV, Y-PSL orientation provides full power with continuous earth pointing. Preliminary investigations indicate the CMG torque limitations may not allow the body rates to exactly provide this orientation but could come very close. Earth pointing FOV's would rotate at variable rates about the nadir. The acceptability of these factors needs to be evaluated.)

This discussion has not distinguished between principal and geometric axes when referring to orientation. From a controls viewpoint it is generally desirable to orient about the principal axes to minimize CMG desaturation requirements. However, from a payload viewing standpoint orientation should be about the geometric axes. By example, in a Y-PSL orientation if the Y geometric axis is displaced from the Y principal axes by more than 0.5 degree and the principal axis orientation is employed, the EO-1 solar viewing sensor will not have the sun within its Field-of-View. Further work should be performed in this area.

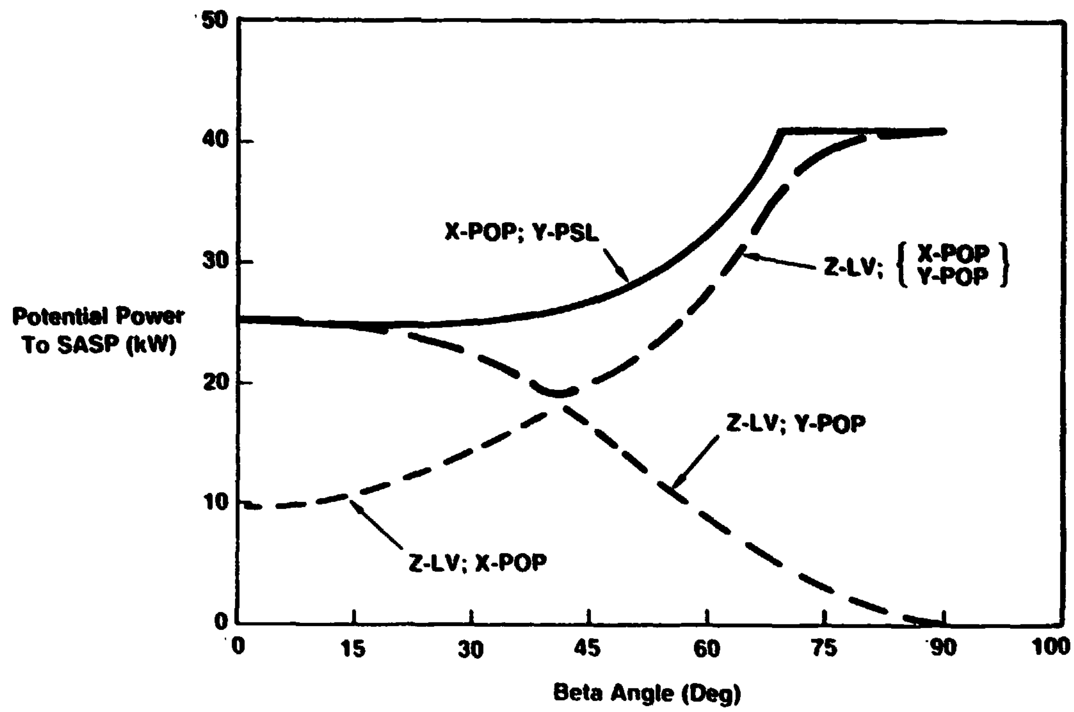
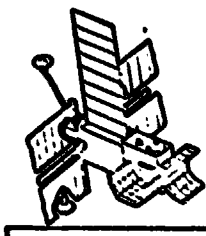


Figure 2.8-3 Power Available

2.9 ACCELERATION LEVELS

As defined in Section 2.1, Materials Processing and Life Sciences place acceleration limits on SASP operations. The Materials Processing class of experiments imposes the more stringent requirement; $< 1 \times 10^{-5}$ g's. This constraint is the design driver. In the operation of the Platform this constraint helped drive the reboost interval to 90 days to minimize interference with the Materials Processing experiment. In Figure 2.9-1 the acceleration environment for the 1st Order Platform is presented.

The rigid body linear accelerations at the outer ends of rear and side pallets for a Sortie-Combo and a Free-Flyer configuration are shown for several disturbance sources. The aero drag variation is due to diurnal bulge atmospheric density variations and the orbital variation of the projected area perpendicular to the velocity vector. A solar activity of 150×10^{-22} $watt^2/sec$ (nominal 1991 solar maximum) and an altitude of 435 km was assumed.



DISTURBANCE SOURCE	ACCELERATION (10^{-6} G'S) SORTIE COMBO REAR PALLET	SORTIE COMBO SIDE PALLET	FREE-FLYER REAR PALLET	FREE-FLYER SIDE PALLET
AERO DRAG				
X-POP, Y-PSL	0.04 – 0.2	0.04 – 0.2	0.1 – 0.9	0.1 – 0.9
Z-LV, Y-POP	0.02 – 0.2	0.02 – 0.2	0.05 – 0.8	0.05 – 0.8
ORBITAL MECHANICS				
X-POP, Y-PSL	1.8	1.8	0.87	0.88
Z-LV, Y-POP	1.9	1.9	0.38	0.56
0.1 DEG/SEC MANEUVER WORST DIRECTION	2.5	3.5	2.0	1.4
PAYLOAD SLEWING (RIGID BODY) ASPS MAX (34 N-M)	1.7 – 6.1	2.8 – 7.3	4.1 – 46	14 – 26
CMG TORQUES				
MINIMUM (0.33 N-M)	0.017 – 0.061	0.028 – 0.073	0.041 – 0.46	0.14 – 0.25
TYPICAL (14 N-M)	0.72 – 2.6	1.1 – 3.1	1.7 – 20	5.9 – 11
CREW DISTURBANCE (8–215N, PITCH)	14 – 360*	16 – 420*	110 – 3000**	81 – 2200**
ORBITER VRCS (2 THRUSTERS) PITCH UP	290	360	–	

NOTE: MATERIALS PROCESSING REQUIREMENT IS 10^{-5} G's

*INPUT IN LOWER CABIN

**INPUT ON AFT END OF AFT PALLET

Figure 2.9-1 Disturbance Accelerations for First-Order Platform

The orbital mechanics and maneuver g-levels are higher for the Sortie-Combo configuration because the distance from the c.g. is greater.

Payload slewing and CMG disturbances vary because the moments-of-inertia vary from axis to axis. The 34 NM ASPS disturbance torque corresponds to the maximum gimbal moment capability for APS's* being considered. Note that for the Free-Flyer configuration the 34 NM disturbance results in g-levels in excess of the 10^{-5} g materials processing requirement so that some payload slew acceleration limitations will be imposed. The CMG torques correspond to Skylab data. The typical value is an estimate based on the fact that Skylab operated with a torque limit of 55 N-M (1 deg/sec gimbal rate limit) during most of the later flight. It was assumed that short term oscillations required

25 percent of the limit. Momentum management maneuvers (occuring several times per orbit) reached the 55 NM limit, however. Therefore, the SASP attitude control and momentum management schemes used during low-g operations will be specially designed for the low-g mode to achieve the 10^{-5} g requirement.

The Orbiter disturbances exceed the requirements threshold from a materials processing viewpoint. The small Orbiter thrusters (VRCS) result in well over the 10^{-5}g requirement. Even minimum crew disturbance levels appear to exceed the 10^{-5}g requirement. For this study, materials processing experiments were assumed to be performed only in Free-Flying modes.

Figure 2.9-2 presents corresponding data for an Extended 2nd order configuration. The larger inertia of the configuration reduces somewhat the acceleration due to torques. However, the ASPS 34 N-M torque still causes acceleration levels greater than 10^{-5}g's. Torque shaping called for in the 1st Order Platform will also alleviate this condition.

*Auxiliary Pointing Systems

	ACCELERATION (10^{-6} G'S)	
DISTURBANCE SOURCE	PALLET AT END OF CROSS ARM	PALLET ON SUPPORT MODULE
• ORBITAL MECHANICS		
X-POP, Y-PSL		
Z-LV, Y-POP	3	1
• 0.1 DEG/SEC MANEUVER		
(WORST DIRECTION)	4	2
• PAYLOAD SLEWING	20	15
(ASPS, 34 N-M)		
• CMF TORQUES		
MINIMUM (0.33 N-M)	0.2	0.14
TYPICAL (14 N-M)	8	6
• AERO DRAG		
X-POP, Y-PSL		
Z-LV, Y-POP		

Figure 2.9-2 Disturbance Accelerations for 2nd Order Platform

2.10 PLATFORM SIZING

Early in configuration development it was recognized that certain payload dimensions (e.g., antennas, tethers, etc.), could lead to payload/Power System collisions unless care was exercised. Consequently, payload maximum dimensions were analyzed to determine how configuration dimensions such as berthing port separations and standoff clearance between the Power System and Platform should be determined (see Figure 2.10-1).

Platform sizing requirements were developed and are summarized in Figure 2.10-2. These reflect the Orbiter payload bay constraints, the desire to avoid payload-to-payload and payload-to-solar array interferences, the desire to satisfy the maximum number of candidate payloads and the desire for both configuration commonality and growth capability. The initial assumption was that either gimbal locks or software programming could avoid interferences; however, frequent payload loading changes would make this approach subject to frequent change and possible safeguard failure. Consequently, analysis focused on selecting a payload length limit which would assure payload/Power System (PS) clearance. Subsequent study should re-examine this decision as Platform and PS designs are further developed and representative payload requirements are affirmed.

A cumulative payload percentage with maximum dimension equal to or less than a given value was developed to see if a logical standoff distance could be determined. These results are plotted in Figure 2.10-3. The curve has a logrithmic scale for payload length and it is evident that required standoff distances increase rapidly above the 10- to 12-meter size while percentage capture increases slowly. Figure 2.10-4 illustrates this point more clearly and a 12-meter payload size (83% capture) was selected. As can be seen the

next larger payload is 18 meters in length and represents a two percent increase in capture percentage. The 12 meter payload size permits the standoff structure to be rigid (non-deployable) so that structural free play could be minimized, the outer surface could be used for ground-installed radiators, and cost minimized. Figure 2.10-4 also illustrates that a significant number of payloads should be flown in a trail arm location to avoid the potential solar array interference present with the cross arm mounting. These larger payloads are given further definition in Figure 2.10-5. It can be seen that all could be flown on the configuration shown in Figure 1.5.2-2; however, platform orientation must be restricted to an airplane mode (e.g., Z-LV) with limits imposed on cross arm rotation. Some of the payloads (e.g., SOI-3, and SP-5) would be candidates for solo flight due to payload interference with all the cross arm positions.

With selection of Platform/PS standoff requirements were established for docking port separations. These are summarized in Figure 2.10-6. Interport distances were analyzed for payloads on the same arm and pointed towards one another. The limiting case occurs with payload gimbal angles of 30 to 60 degrees. As identified in Figure 2.10-6 the limiting case occurs for the Astronomy/High Energy physics payloads with the four largest payloads (12 meters) as indicated. At a port separation of 13.2 meters, AOI-1 and AMIP-3 can be flown together without risk of collision. Thus, payloads HE10/11 and AOI-1 cannot be flown on the same arm unless gimbal travel is constrained.

The limiting case for abutting arms occurs with celestial and earth viewers. A distance of 9.53 meters (see Figure 2.10-1) will assure adequate clearance between AOI-1 and R-34 (Soil Moisture Radiometer). No problems will be encountered with R-48 (Ocean Synthetic Aperture Radar) since the phased

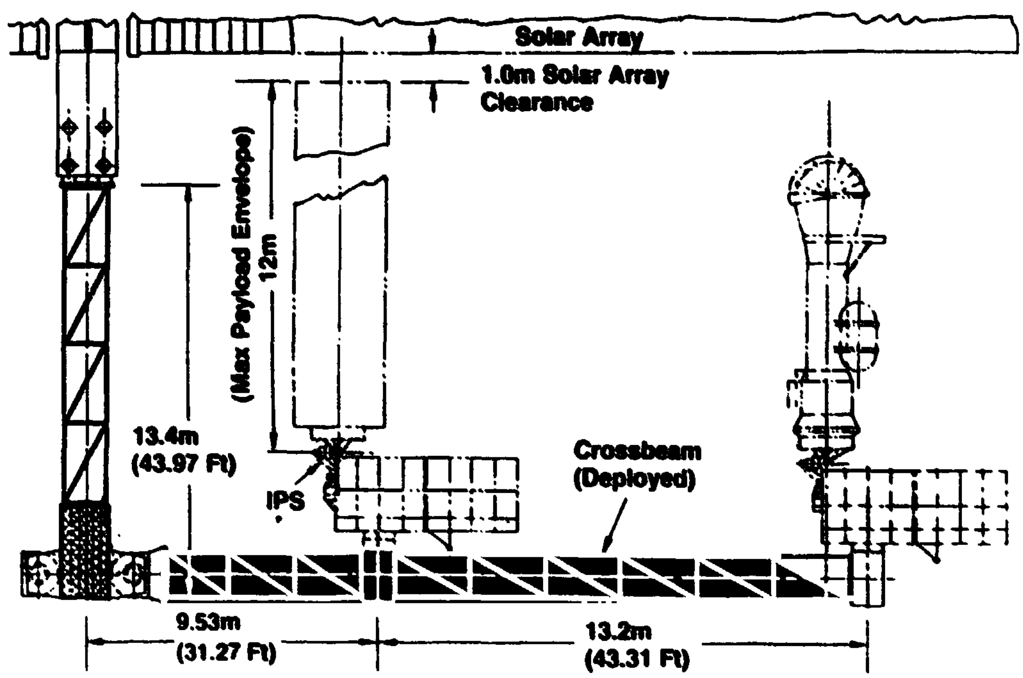


Figure 2.10-1 Platform Sizing

- **Fit Platform Into Payload Bay With OMS Kit and Docking Adapter (13.4 Meters)**
- **Prevent Collision Between Payloads and Solar Arrays**
- **Prevent Collision Between Adjacent Payloads**
- **Satisfy the Maximum Number of Payloads**
- **Minimize Structural Free Play**
- **Maintain Commonality Between Configuration Options**
- **Maintain Growth Option**

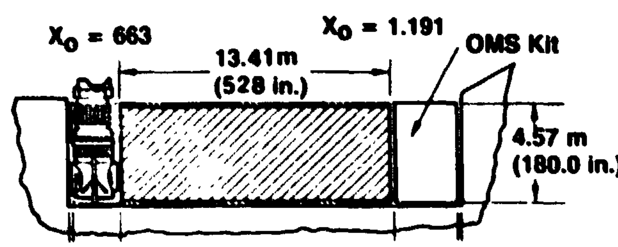


Figure ..10-2 Platform Sizing Requirements

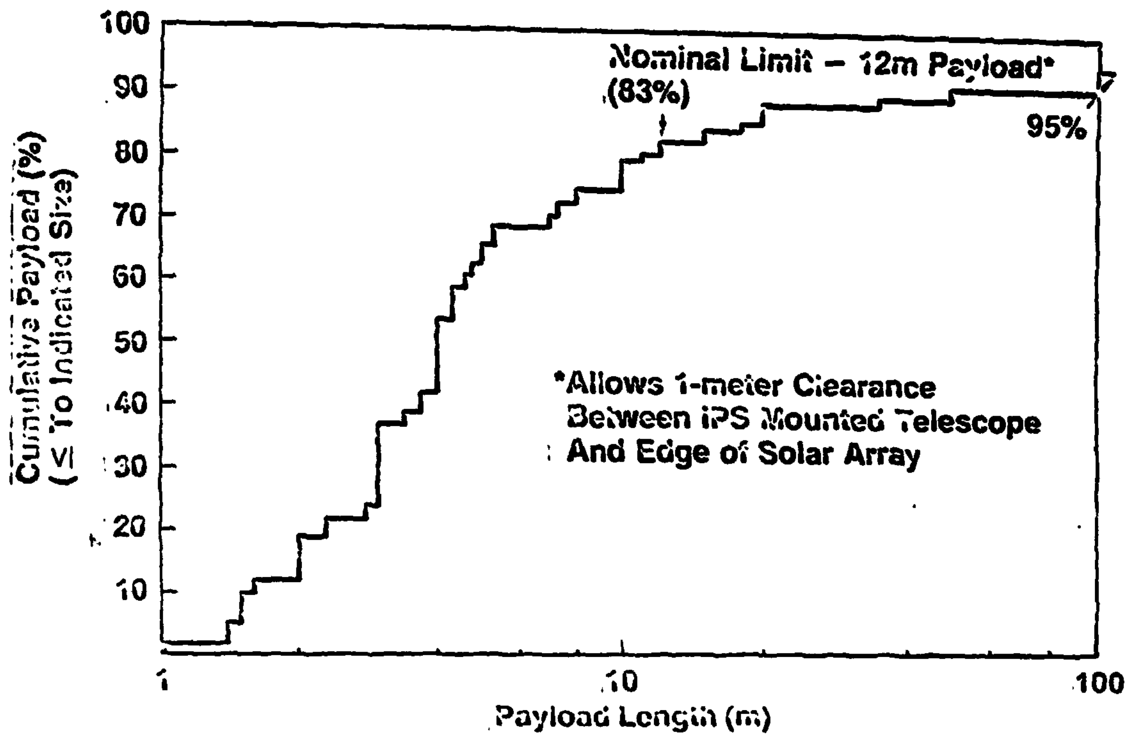


Figure 2.10-3 Maximum Payload Size

Code	Length (Meters)	% of Payloads ≤ This Length
HE-10/11	10	—
R-34	10	—
R-35	10	80
R-46	11	81
AOI-1	12	83
AOI-2	18	85
R-48	20	86
AMP-5	35	88
SOI-3	100	—
SP-5	100	—
SOI-1	100	93
SOI-2	1,000	95
SPP-3*	10,000	97
SMIP-2*	100,000	—
R-37*	100,000	100

*Tether Payloads

Figure 2.10-4 Maximum Payload Dimensions

• AOI-2	Astrometric Telescope	(18 × 2m Dia)
• AMIP-5	IR Telescope	(35 × 15m Dia)
• SOI-3	Atmospheric Gravity Wave Antenna	(100m Dia)
• SP-5	Pinhole Camera	(100m Boom)
• SOI-1	Particle Beam Injection	(100 × 100 × 10m)
• SOI-2	Pinhole Camera	(1 km Boom)
• SPP-3	Wave Particle Interaction	(10 km Tether and 300m Antenna)
• R-37	Geomagnetic Field Tether	(100 km)
• SMIP-2	Tether	(100 km)

Figure 2.10-5 Payloads Requiring a Trail Arm Configuration

REQUIREMENTS

- ±60° Gimbal Travel – Pointing
- Avoid Payload Collisions
- Only Common Technology Payloads Per Arm
- Payloads > 12 Meters To Fly On Trail Arm

LIMITING CASES

- Single Arm – Celestial Viewers

AST-5	1 × 5 × 1m	
AMIP-3	5 × 1.5m Dia	
HE-10/11	10 × 5m Dia	13.2m
AOI-1	12 × 3 × 3m	

- Abutting Arms – Celestial and Earth Viewers

AOI-1	12 × 3 × 3m	9.53m
R-34	20m Dia (Parabolic)	
R-46	11 × 4 × 4m	
R-48	20 × 2 × 0.2m	

Figure 2.10-6 Docking Port Separations Cross-Arm Configuration

array would be flown either parallel to or normal to the cross arm without a gimballed pointing system.

Assuming that a trail arm configuration may be developed for the larger payloads (see Figure 2.10-5) it appears that a 13.2 meter interval maximum would be appropriate. This is based on the rationale that other payloads should be able to fly this configuration with minimum constraints as well as the nine oversized payloads.

Figure 2.10-7 summarizes the sizing features and sensitivities of the selected configuration.

Separation Distance (m)	Percentage of Payload Lengths Accommodated* (Lengths: 38%≤3m, 28% 3-5m, 17% 5-12m, 7%18-20m, 10%≥20m)		
	Solar Panel Avoidance	Adjacent Payload Avoidance (120° IPS Sweep Cone)	Berthing with RMS
7.5	65%	(Inner Ports) 72% (Two 8m Payloads)	100% (Both Inner Ports)
9.5	75%	(Design Point) (Inner Ports) 75% (Two 10m Payloads)	(Design Point) 100% (Both Inner Ports) (Max RMS Reach)
11.0	80%	83% (Two 12m Payloads)	1 Inner Port Only
13.5 (Max Solid Arm Length/Cargo Bay; OMS and Docker)	(Design Point) 83% (12m Payload)	(Design Point) Outer Ports 70% (Two 7m Payloads)	0
≥ 21.5	90%	83% (Two 12m Payloads)	0

*Payload Diameters and Shape also Influence Platform Sizing

Figure 2.10-7 Second Order Platform Size Sensitivity

2.10.1 Platform Shaping

An extensive evaluation was made of numerous approaches to basic platform shape. Figure 2.10.1-1 illustrates the candidates studied. The conclusion reached from this analysis is that the "Horizontal Tee" configuration and subset of it, "Trail Arm" and "Cross Arm", have superior capabilities when employed with the Reference 25 kW Power System. Figure 2.10.1-2 lists some of the criteria applied in the configuration selection process.

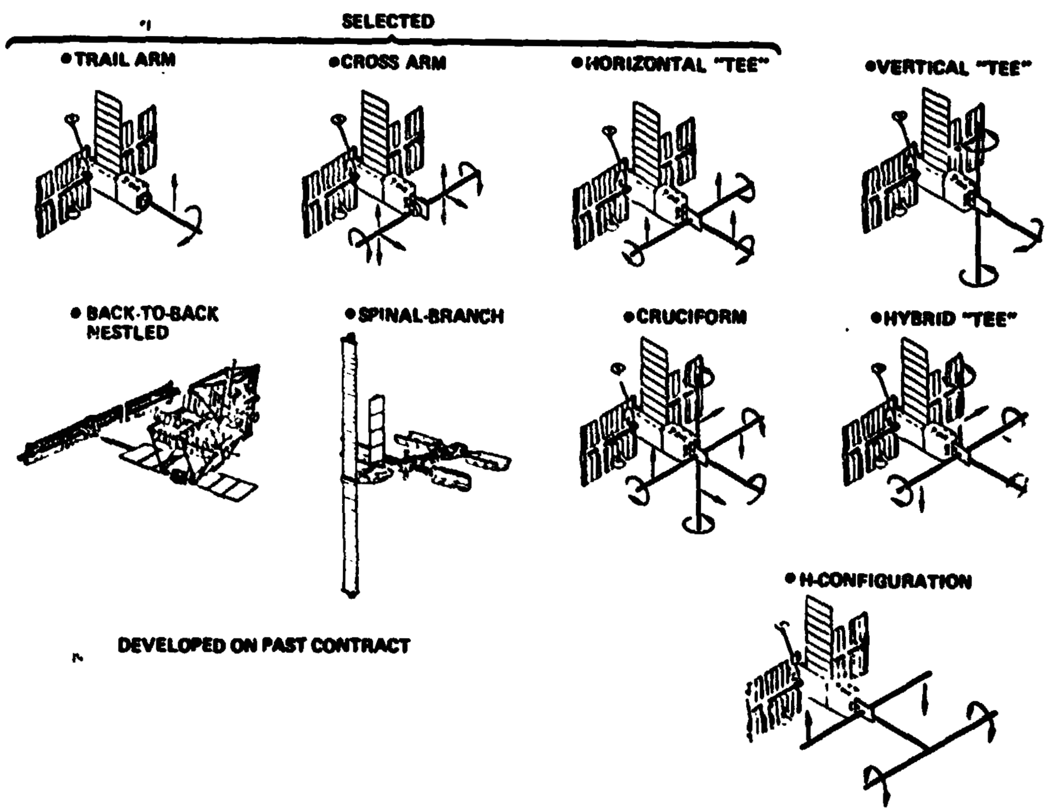


Figure 2.10.1-1 Configurations Evaluated

- DEVELOPMENT RISK - SIMPLICITY OF DESIGN, TECHNOLOGY STATUS, NEED FOR NEW TOOLING OR MACHINING, COMPATIBILITY WITH ANALYSIS METHODS, TESTABILITY
- GROWTH CAPABILITY - SUITABILITY OF DESIGN FOR INCREASED SIZE, POWER, IMPROVED ATTITUDE CONTROL, ETC
- INERTIA DISTRIBUTION - RELATIVE EASE OF VEHICLE CONTROL
- EASE OF PLATFORM ASSEMBLY OR DEPLOYMENT - SIMPLICITY OF OPERATIONS, DEPLOYMENT COMPLEXITY, NEED FOR AIDS OR SPECIAL EQUIPMENT, PACKAGING DENSITY/NUMBER OF LAUNCHES REQUIRED
- RESPONSIVENESS TO PAYLOAD/MISSION REQUIREMENTS -
  - SIMULTANEOUS MULTIPLE-VIEWING DIRECTIONS
  - SPACE FOR OVERSIZED PAYLOADS
  - MINIMUM VIEW BLOCKAGE

Figure 2.10.1-2 Selection Criteria

2.10.2 Oversized Payloads

A number of candidate payloads are clearly too large for joint flight with others on the size-class of Platform being addressed in this study. They are listed in Figure 2.10-2-1. These payloads, therefore, were relegated to accommodation on the (large) Advanced SASP studies under a parallel contract for LARC/MSFC, as illustrated in Figure 2.10.2-2.

		ORIENTATION
•SOI-1	PARTICLE-BEAM INJECTION (100 X 100 X 10m)	MAGNETIC
SOI-2	PINHOLE CAMERA (20m DIAM + 1kM BOOM)	SOLAR
•SOI-3	ATMOSPHERIC GRAVITY WAVE ANTENNA (100m DIAM X TBD)	EARTH
••SOI-4	MAGNETIC PULSE (1kM ANTENNA)	NA
R-9	MARK I RADIOMETER (20m DIAM)	EARTH
AMIP-5	IR TELESCOPE (35m X 15m DIAM)	CELESTIAL
AOI-2	ASTROMETRIC TSC (18m X 2m DIAM)	CELESTIAL

•DROP-SIZE

••DROP-ALTITUDE

Figure 2.10.2-1 Oversized Payloads

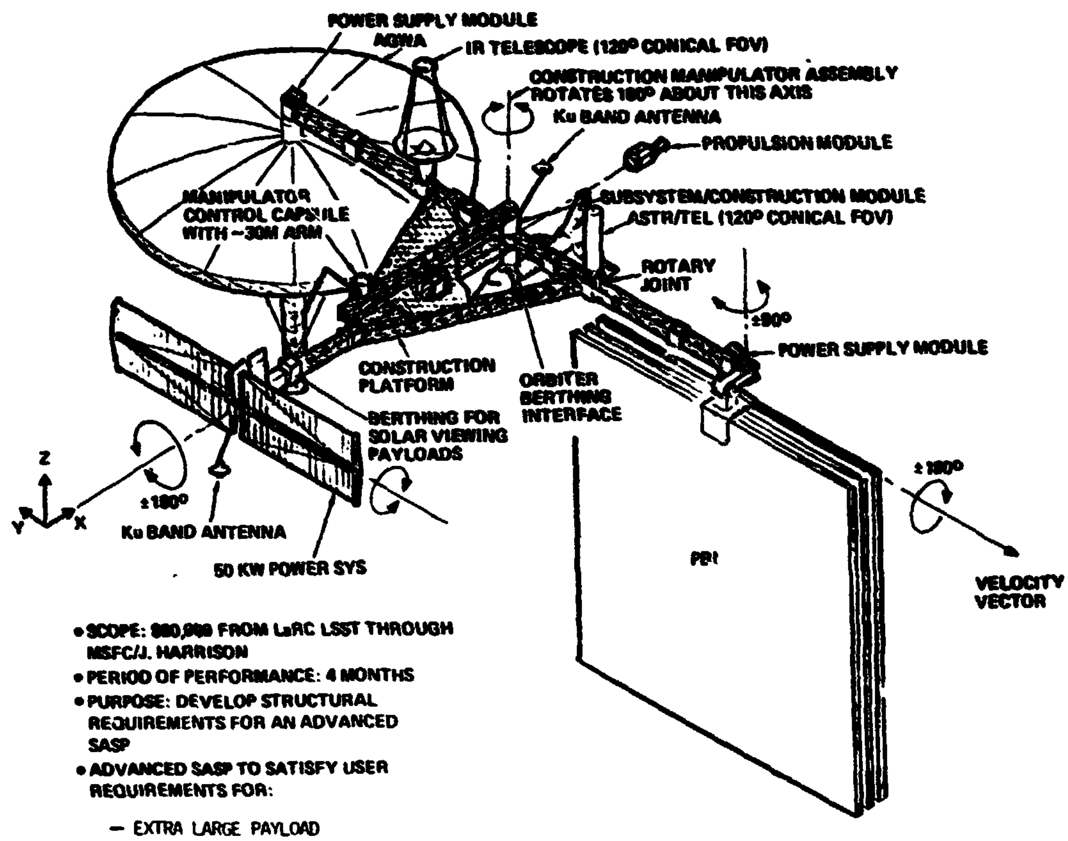


Figure 2.10.2-2 Advanced Science and Applications Space Platform Concept Study

2.11 FIRST ORDER PLATFORM DEVELOPMENT

Using the Power System with only minimal additions as an early, low cost Platform merits consideration. The evolution of those additions necessary to make this operating mode viable for viewing experiments is discussed in the following paragraphs.

2.11.1 Requirements

The set of requirements employed in the development of the design are:

- Permit simultaneous viewing in three directions
- Payload viewing directions are Solar, Earth, Anti-earth, Gravity Gradient, Celestial, and Magnetic
- Power System Orientations as needed

- Durations - 3 to 4 months
- PS subsystem/payload service compatibility
- Preclude collisions between payloads and between payloads and PS elements
- Minimum transition for payloads from Spacelab Sortie Mode (see Figure 2.11.1-1).

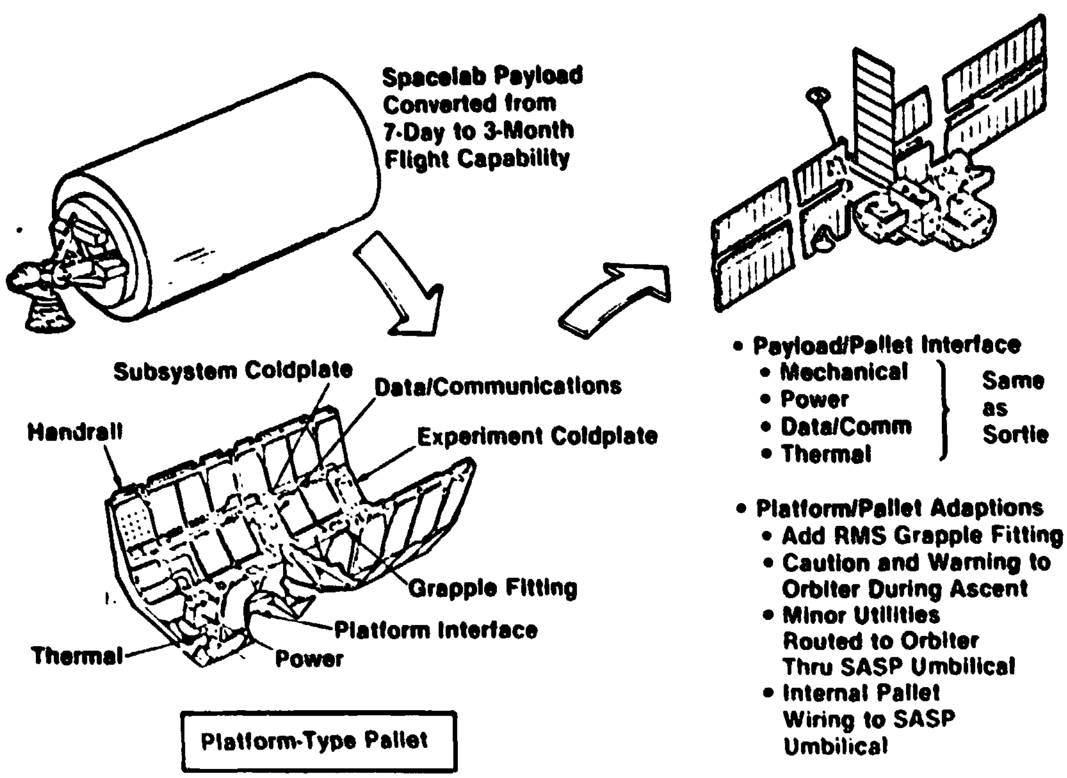


Figure 2.11.1-1 Minimal Transition for Payload/Pallet Interface

2.11.2 Configuration Options

The options considered were:

1. Pallets bottom mounted directly to the PS (fixed).
2. Pallets end-mounted to the PS (fixed).
3. Pallets bottom mounted directly to the PS (rotatable).
4. Pallets end-mounted to the PS (rotatable).
5. Pallets bottom mounted to mini-arm (4-position fixed).
6. Pallets bottom mounted to mini-arm (4-position commandable).

Details of these options can be found in Section 4. Employing the viewing requirements quickly eliminates Options 1 and 3, with pallets bottom mounted to the Power System. For the PS ports of interest (+Y, -Y, +X, and +Z) and an experiment sensor mounted on the pallet looking out (Option 1) there is major FOV obscuration from the +Z, +Y, and -Y ports, leaving only the +X port as a viable viewing candidate. Adding rotation, Option 3 provides no benefits only rotating the instrument FOV about itself.

2.11.3 Payload Interference

For the reference PS design interference will exist for payload/pallets that are directly mounted on the PS ports. This interference occurs between pallets and any payload overhang will aggravate tne problem. Figure 2.11.3-1 illustrates the basic interference problem.

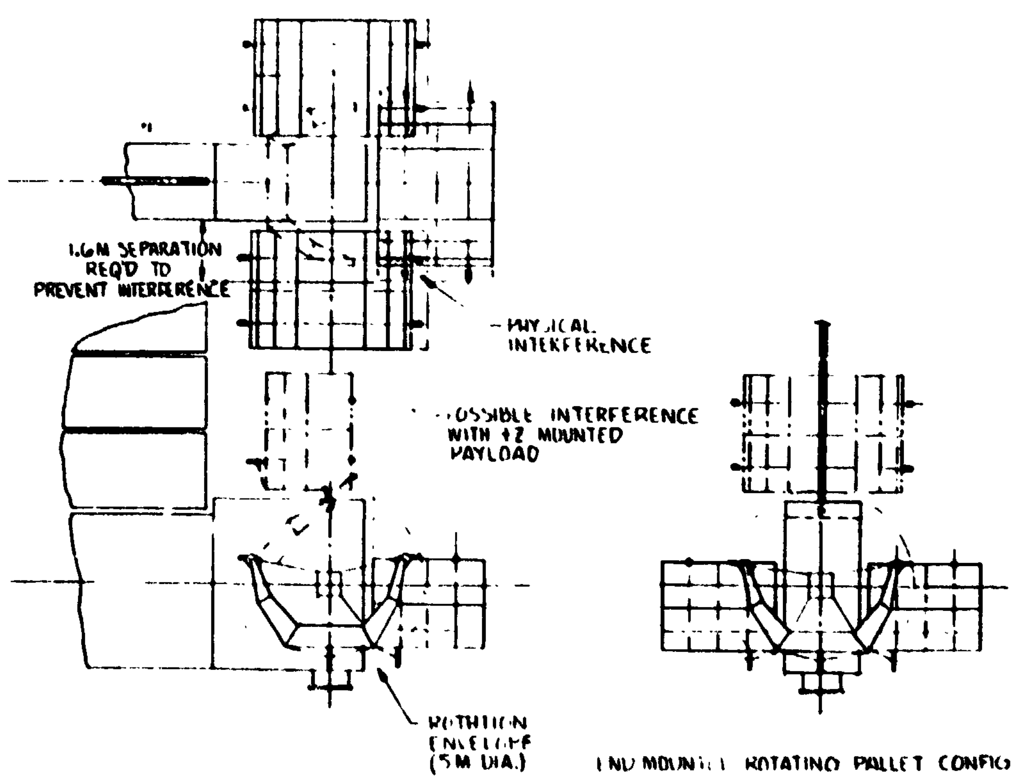


Figure 2.11.3-1 Payload Interference - End Mounted Rotating Pallet Configuration

The +Z port poses a potential collision risk with the PS radiator unless the payloads either are constrained to deny viewing in the +Z direction or limited to prevent gimballed payloads from viewing in the +Z direction. In effect, the +Z docking port has greater interference risk than do the +X or ±Y ports. It is recommended that further study be given to the suitability of the +Z port as additional payload requirements emerge for flight on the First Order Platform.

2.11.4 Viewing Comparison

Quantitative comparisons were made between the fixed and on-orbit commandable pallets mounted on mini-arms. Figure 2.11.4-1 illustrates the results of this comparison. Percent of the celestial sphere visible at any instant in time is shown for both options. As shown the flexibility provided by the commandable four-position concept is clearly superior (more than double that portion of the) sky that an instrument can view) and approaches, in certain situations, that visible from a dedicated spacecraft. (Assumptions include: 15 degree exclusion zone about earth, and all platform elements, and a 60 degree gimbal capability. Shaded areas indicate continuous visibility; a dashed-boxes obscuration by the earth over a portion of the orbit. Lower plots show schematically how viewing from each mini-arm varies over the orbit period.)

2.11.5 Configuration Selection

From the preceding analyses the following conclusions were drawn. First, that standoff structure is required to preclude interference of rotatable pallets and second, that commandable multiposition pallet viewing is clearly superior to fixed pallet viewing. MDAC selected the three-position rotation plus hinge (4-position) over a fully rotatable capability with hinge to reduce both cost and complexity while still providing the required viewing capability.

Commandable Miniarms Enhance Visibility

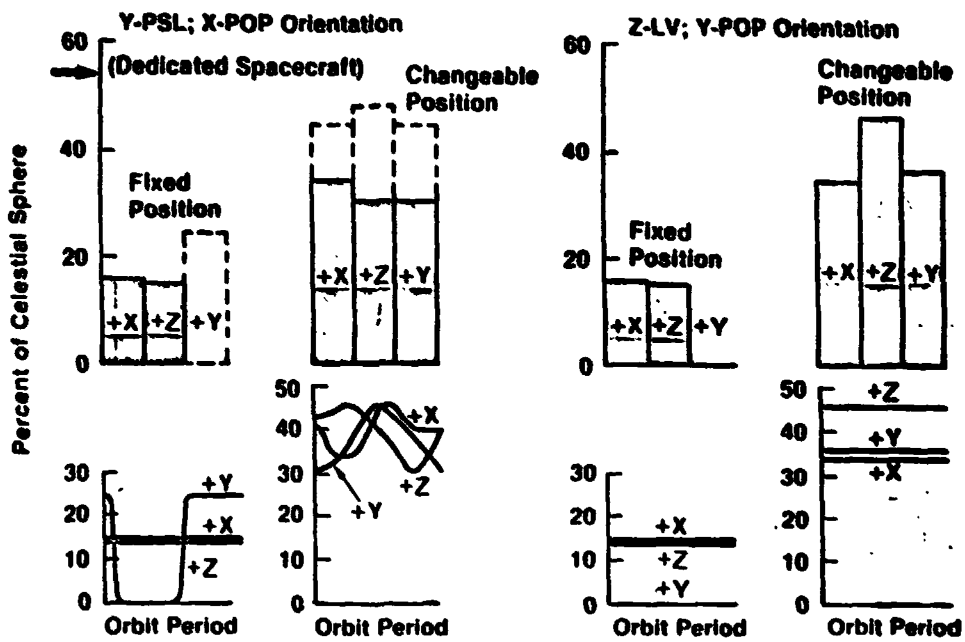


Figure 2.11.4-1 1st Order Platform Visibility - II

To resolve the interference problem and to provide both gimbal and hinge movement requires a standoff structure about three meters long. Each mini-arm uses a single three meter segment of the structure designed for the 2nd Order Platform.

2.11.6 Bottom Versus End Mounting

The trade for pallet mounting (end, bottom, or side) is reported in Section 5 and bottom mounting was selected. For convenience, the pros and cons for bottom and end mounting are updated and repeated here. (These considerations did not consider the implications of a hinge.)

END MOUNT

Pros

- Permits $\pm$Z and +X viewing from $\pm$Y ports.
- End attachment close to current umbilical location

BOTTOM MOUNT

Pros

- Mechanical/electrical interface same as Platform
- No impact on cargo bay volume

Cons

- Increases pallet length, reduces Shuttle volume at launch
- Structural attachment will constrain payload volume/space
- Cantilevered support increases "jitter" and pointing error due to thermal distortion
- Heaviest structural interface
- 90° hinge still required to assure multiple pointing capability. Hinge can lead to interpallet interference.
- If used for 2nd Order Platform, effective standoff to solar array is reduced.
- A 1.6 meter standoff is needed to prevent interference during rotation.

- Least weight penalty
- Less thermal distortion error
- Minimum standoff needed to preclude interference

Cons

- Interface is smaller than Orbiter/PS interface
- Need remote TV viewing of pallet/PS interface during docking
- Requires 90° hinge to assure multiple pointing capability

Based on review of the above, the bottom mounted pallet decision is affirmed.

2.11.7 Evolution and Growth

The recommended Payload Support Berthing arms can be used with the Second Order Platform either at the PS docking ports or as simplified trail arm positions. Subsequent study should consider making the arms capable of orientation at any angle of rotation with a $\pm 180°$ capability. Mechanical gimbal stops could be incorporated when used on the PS.

By providing payload rotation and second axis hinge movement, the berthing arms make minimum impact on Power System services, except for the recognized need for +Y port additions.

Section 3
PLATFORM/25 KW POWER SYSTEM ANALYSIS
(Task 3)

3.1 OBJECTIVES

The objectives of this task were to (1) define the requirements which the space platform system elements impose on the 25 kW Power System, (2) determine via trade studies the most cost effective interface between the two systems, and (3) identify recommended interfaces and desirable modifications to the 25 kW Power System.

This section of the report first presents a summary tabulation of interface comments for both First and Second Order Platforms. Following this are individual subsystem discussions of the subject interfaces.

3.2 SUMMARY

Table 3.2-1 provides summary interface comments which are intended to form a basis for discussions between the Power System and SASP organizations.

1st Order Platform	2nd Order Platform
Power	
• Provide 25 kW 30 and 120 VDC at One of the y Ports • Consider Adding Higher Power Capacity at One y Port for Unique Applications • Provide 6 kW 30 and 120 VDC at the ± y Ports • Terminate Equipment Grounding Conductor from Miniarms	• Consider Means to Bypass 120 VDC Regulator • Consider 12.5 and 25 kW Options • Provide a Third Isolatable 120 VDC Bus Interface • Terminate Equipment Grounding Conductor from Platform Support Module
Thermal Control	
• Provide Thermal Services to ± y Ports (Pumps in PS) • Performance Characteristics of PS Payload Heat Exchanger and Temp Control Logic Needed • NASA Alternatives to Freon 21 • NASA-MSFC Work on Disconnects	• Additional Heat Rejection Capability for Payloads • Performance Characteristics of PS Payload Heat Exchanger and Temp Control Logic Needed • Temp Control System Modifications for 40°F Service to Life Science Payloads • NASA Alternatives to Freon 21 • NASA-MSFC Work on Disconnects

Table 3.2-1 Platform/Power System Interface Comments

1st Order Platform	2nd Order Platform
Communication Data	
• Increase KSA Link Capability to 300 MBPS • Increase Capacity at SASP Port to 300 MBPS • Increase Continuous Channel Capacity to Approximately 200 KBPS • Increase Data Storage Capability	• Increase KSA Link Capability to 300 MBPS • Increase Capacity at SASP Port to 300 MBPS • Increase Continuous Channel Capacity to Approximately 200 KBPS • Timing and Position Data from GPS Are TBD
Attitude Control	
• Low-G Attitude Control Mode • PS Structural Distortion? • Pointing Reference Coordination • Berthing Alignment Accuracy • Control System Bandwidth?	• Low-G Attitude Control Mode • PS Structural Distortion? • Pointing Reference Coordination • Berthing Alignment Accuracy • Control System Bandwidth? • Supplemental Control Versus Axis Skewing • Cooperative Control Between PS, SASP, and Pointing System Computers
Docking	
• Provide · y Ports • Mechanical/Functional Interfaces • Orbiter Berthing Adapter to Provide Access to All Necessary Parts	• Mechanical/Functional Interfaces • Telescoping Boom or Equivalent for Orbiter Berthing and Servicing

Table 3.2-1 Platform/Power System Interface Comments (Continued)

3.3 SUBSYSTEM DISCUSSIONS

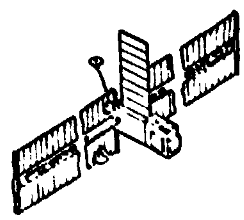
Figure 3.3-1 lists the subsystem capabilities inherent in the reference Power System used in this study as defined in the NASA/MSFC document, same title, PM-001 (preliminary). Figure 3.3-2 illustrates the two basic Power System operating configurations for platform utilization, namely, 12.5 and 25 kW sizes.

3.3.1 Power System Interface

3.3.1.1 Power Interfaces Requirements

The 1st Order Platform introduces requirements for a 25 kW average power interface capability at both 30 VDC and 120 VDC at the PS +Y, -Y, and +X docking ports. These requirements are driven by the Materials Experiment Carrier (MEC) which can dock at any one of the three ports. Based on Power

POWER
- 25 kW Minimum Continuous
- 28 and 120 VDC
- Peak Load Capability >25 kW
- Growth: 50 kW
- Increment: 12.5 kW
- Single Point Reference Ground
- Bus Overvoltage Protection



STABILIZATION AND CONTROL
- Pointing Control
  - Accuracy 0.3° to 2°
  - Stability ~1 min at Best
- Maneuvering
  - 50 Deg/Min Rate (Max)
- Low-G Environment
  - 10^{-6} - 10^{-4} g's
  - Depends on Payload Location
- Orientation Hold
  - 13,800 Ft-Lb-Sec Momentum Storage Capability (Max)
  - CMG Desaturation Assistance from Magnetic Torquers

THERMAL CONTROL
- Heat Rejection (Beta Angle Dependent)
  - 10-16 kW at 25 kW Power
  - 13.5 - 17.5 kW for for Cooling Equal to Power Output
  - Higher Heat Rejection at Lower Power Output
- 3 Fluid Interfaces
- Temperature Control at 60°F to Payload

DATA AND COMMUNICATIONS
- 50-100 MBPS per Payload Port
- 223 MBPS Total (Single Access)
- 46 kBPS Total (Multiple Access)
- 300 kBPS Forward Link
- High Rate Multiplexing
- Limited Computational Capability for Payload Support

REBOOST MODULE
- 4 Axial Thrusters at 40 lb each
- 8 ACS Thrusters at 7.4 lb each
- Monopropellant Hydrazine
- ~1,100 lb Usable Propellant

PHYSICAL PROPERTIES
- Weight ≈ 12,500 kg (25 kW)
- Dimensions
  - Length (Solar Panels) ≈ 80 m
  - Height ≈ 20 m
  - Length ≈ 13 m
- Berthing Ports
  - Aft Bottom (Orbiter)
  - Forward (Reboost Module)
  - Aft End
  - Aft Top
  - Growth: One on each side

Figure 3.3-1 Reference Power System Description

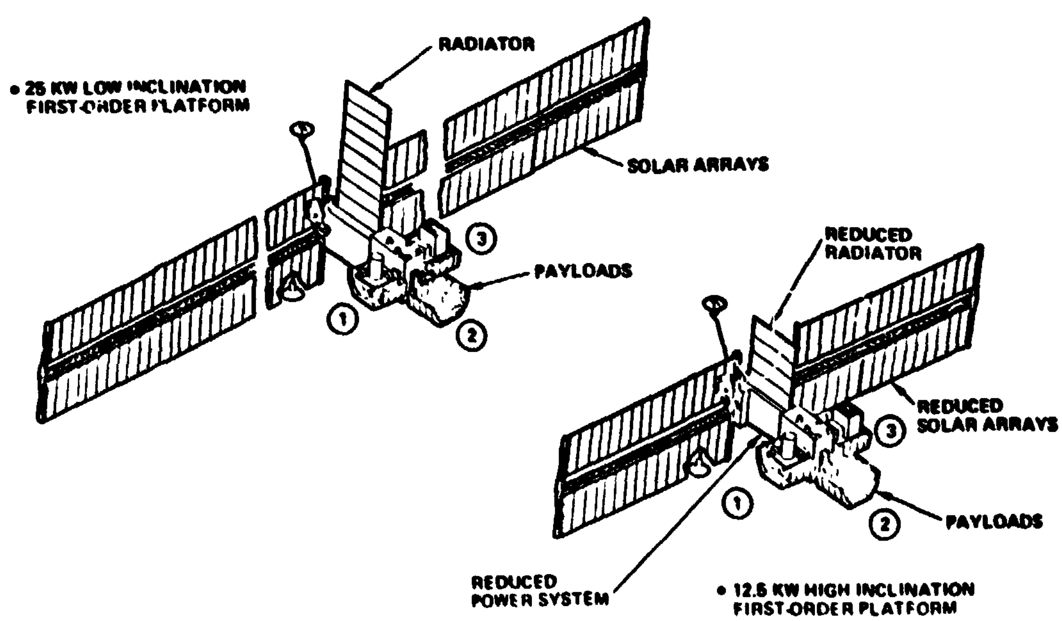


Figure 3.3-2 Platform Utilization Modes

System position (PMCCP) peak power capability required at each port is 35.3 kW @ 30 VDC and 36.0 kW @ 120 VDC. The latter reflects the indicated potential power capability versus the rated capability of 27 kW and, therefore, should be considered as a desired capability rather than a hard requirement.

The requirements for the +X docking port are also driven by provision for growth to the 2nd Order Platform. In this case, the capability for 36.0 kW at 120 VDC is more substantive because of the potential for simultaneous high power demands from multiple payloads.

3.3.1.2 Work Accomplished

Equipment Ground Bus Interfaces

This requirement applies to the interface with each of the mini-arms in the 1st Order Platform and to the standoff structure interface in the 2nd Order Platform. The need for an equipment ground bus results from the use of graphite epoxy structure (with its relatively high resistivity) for the mini-arms, standoff, and other structural sections of the Platform System. The high resistivity of composite (laminated) graphite epoxy material relative to metal structures such as the aluminum support module for the 2nd Order Platform makes it unsuitable for use as a return path for equipment ground fault currents. A low impedance path is required for such currents to assure proper operation of fault clearing devices such as fuses and circuit breakers.

The required low impedance can be provided by conductors sized to handle the maximum fault currents. These conductors must be suitably bonded to the metallic ground plane used for the primary power single point ground system in the PS.

3.3.1.3 Consider Means to Bypass 120 VDC Regulators

This command derives from consideration of options for utilizing PS available capacity to supply peaking power to payloads as covered in Task 4, Subsystem Trades. The preferred approach to supplying high peak power to payloads served by the Platform is by means of peaking batteries provided by the user. Bypassing the regulator(s) might, however, be a viable alternative in a specific application.

3.3.1.4 Provide a Third Isolatable 120 VDC Bus Interface

This is a recommendation based on providing essentially the same flexibility for bus loading, payload isolation, and switchable source bus redundancy as is inherent in the 30 VDC three-bus interface. The reference concept 25 kW Power System provides for three 120 VDC regulators. This proposal would utilize one regulator for each of the three buses to achieve bus isolation as required.

3.3.1.5 Summary of Power System/Platform Interfaces

Table 3.3.1-1 gives the significant data for each of the power interfaces and equipment ground buses identified previously. Note that the peak kW for to two 120 VDC buses to the mini-arms is 36.0 versus 27.0 as discussed earlier. Similarly the total capability for the recommended 120 VDC three-bus interface on the 2nd Order Platform is 36.0 kW.

Also note that 6 #0 gauge wires are specified for two of the three 30 V buses interfacing with the platform support module. For the third bus, a total of 8 #0 gauge wires are shown. The large number of heavy gauge wires are required to satisfy voltage drop limits on the longer runs. The 8 #0 gauge wires are specifically required for peak loading of the Orbiter/Spacelab interface circuit. An option to providing the full 6 wires or 8 wires at the

PLATFORM	NUMBER OF BUSES	DC VOLTS	KW PER BUS AVG	KW PER BUS PEAK	WIRES PER BUS	TOTAL WIRES	
1ST ORDER	3	30	8.3	11.8	4 NO. 0 GAGE	12	EACH OF THREE MINIARMS
	2	120	12.5	18.0	2 NO. 4 GAGE	4	
	1	–	–	–	2 NO. 0 GAGE(1)	2	
2ND ORDER	3	30	8.3	11.8	4 NO. 0 GAGE	12	EACH OF TWO MINIARMS
	2	120	12.5	18.0	2 NO. 4 GAGE	4	
	1	–	–	–	2 NO. 0 GAGE(1)	2	
	2	30	8.3	11.8	6 NO. 0 GAGE	12	TO PLATFORM SUPPORT MODULE
	1	30	8.3	13.0(2)	8 NO. 0 GAGE	8	
	3(3)	120	8.3	12.0	2 NO. 4 GAGE	6	
	1	–	–	–	2 NO. 0 GAGE(1)	2	

(1) EQUIPMENT GROUND BUS. WIRES ARE SIZED FOR FAULT CURR
(2) REQUIRED TO SUPPLY 11.0 KW PEAK TO ORBITER/SPACELAB INT ... AT 28 6 VOLTS MINIMUM
(3) THIRD 120 V BUS FOR 2ND ORDER PLATFORM IS A RECOMMENDE ... ON TO THE TWO – 120 V BUSES BASELINED IN THE 25 KW POWER SYSTEM REFERENCE CONCEPT

Table 3.3.1-1 25 kW Power System/Platform Power Interfaces

PS/Platform interface would be to limit the interface to four wires per circuit and install a junction box at the PS end of the platform standoff. The required additional parallel wires could be added at this point.

3.3.2 Thermal Control Subsystem Interface with Power System

Heat rejection capability is provided by the reference Power System design through a payload heat exchanger. This capability can conveniently be used to provide a portion of the platform subsystem and payloads cooling requirements.

3.3.2.1 Requirements Summary

Power System interface requirements are summarized in Figure 3.3.2-1. Physical interface requirements in schematic form are shown on the right. The Power System provides accommodations for three payload fluid cooling loops in the form of fluid disconnects, a temperature control valve and a payload heat exchanger passageway. The normal temperature control range for the Power System is 60 to 110°F. Pressure drop and flow characteristics are not yet defined but are assumed typical for this type equipment.

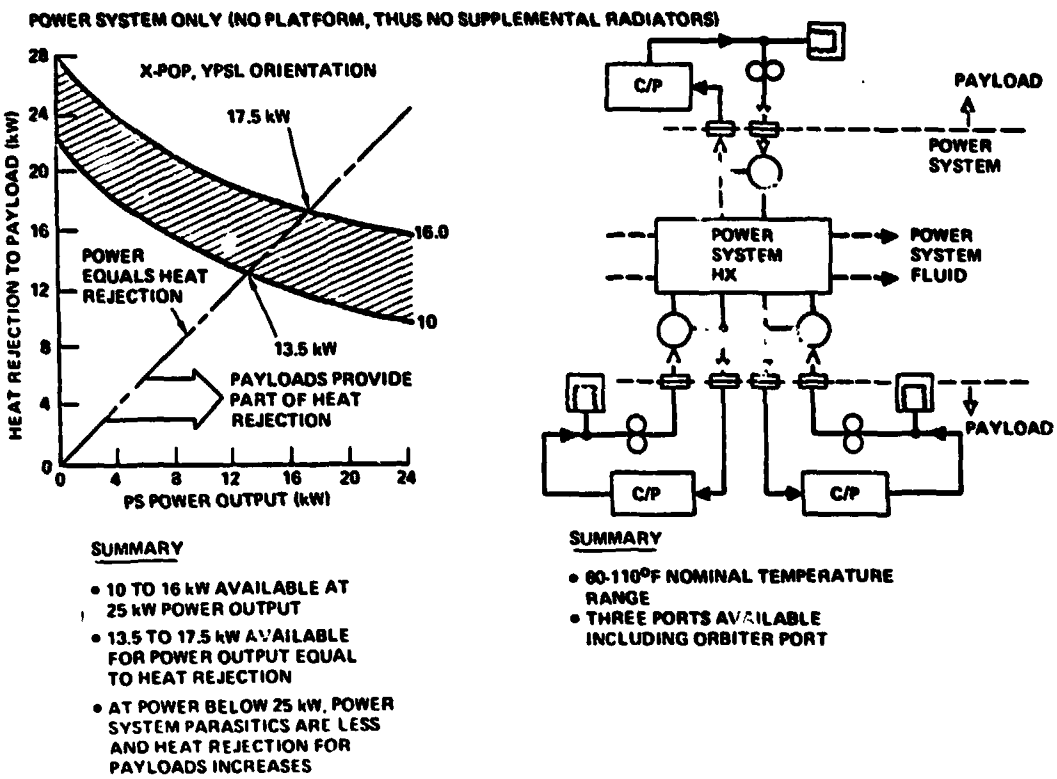


Figure 3.3.2-1 Thermal Control Accommodation
First-Order Platform Mode

Power System performance, in terms of heat rejection, is given on the left side of Figure 3.3.2-1. Performance is a function of power level and beta angle. Best performance is at low power output when Power System parasitic loads are low. Similarly the lowest performance occurs at high power loads to the payload. The minimum performance corresponds to the full 25 kW power output where heat rejection is 10 to 16 kW depending upon beta angle. 13.5 to 17.5 kW of cooling is available for the case where the Power System rejects all power from payloads.

3.3.2.2 Important Factors and Considerations

The reference Power System is designed to receive thermal control fluid at 110°F and maintain a controlled 60°F payload return temperature. This temperature range must be compared to payload requirements to assess the

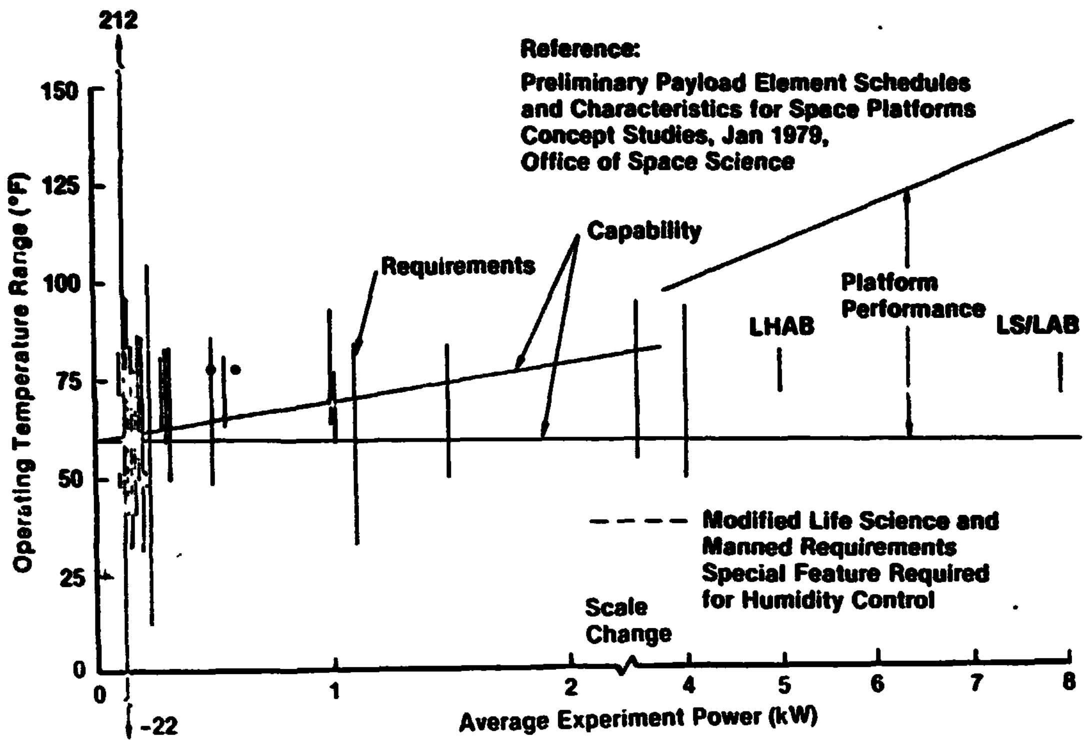


Figure 3.3.2-2 Experiment Temperature and Power Requirements Versus Capability

acceptability of the Power System interface.

Figure 3.3.2-2 gives experiment operating temperature range and average power for the experiments listed in the referenced document. Also superimposed on the chart is the capability of the Platform in terms of fluid temperature versus power for each docking port.

A comparison of requirements versus capability shows that the platform performance is within the acceptable operating range of the experiments. Several very low power experiments exist which are outside the platform range. It is believed that close scrutiny of these experiment requirements will show that platform accommodation is adequate. If not, special provisions such as a heater, recirculation. [illegible] can be used for these low cooling loads.

Data listed for payloads Long Habitability Module (LHAB) and LS/LAB are obviously atmospheric temperature limits. If humidity control requirements of 40°F are included, it can be seen that the platform cooling temperatures are 20°F too high. This lower temperature requirement would dictate a supplemental radiator on the Platform or experiment modules or would require a lower set point for the Power System thermal control subsystem.

The second major payload data source for the study was examined for temperature control requirements. This source is "Strawman Payload Data for Science and Applications Space Platforms, January 1980, SP80-MSFC-2403", by Teledyne Brown Engineering. This data source did not reveal any payloads which could not be accommodated by a 60 to 110°F temperature range.

3.3.2.3 Work Accomplished

A comparison was made of various heat rejection options which impact the Power System thermal control interface. These options include heat rejection by platform radiator concepts, Power System, pallet located radiators, and combinations of these.

Figure 3.3.2-3 compares capability for these heat rejection options and combinations. Also shown are the typical requirements for two port and four port sustained operation assuming 5 kW cooling per port plus platform subsystem loads. Pallet fixed radiator capability is not shown singly but amounts to 2.8 to 3 kW per pallet.

It can be seen that the pallets, Power System, or platform standoff radiators cannot alone reject the required load for the four port requirement. A platform design which uses all non-deployable structural areas of cross arm plus standoff has ample performance. However, this concept would require

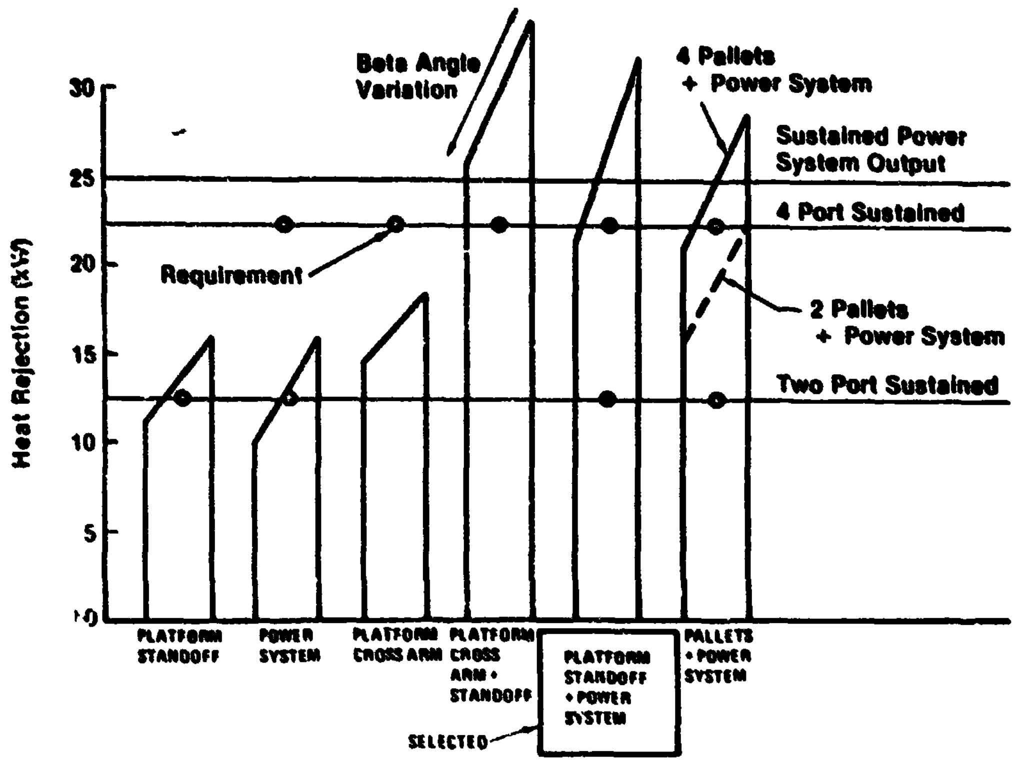


Figure 3.3.2-3 Platform Heat Rejection Options Performance Comparison

three separate radiators and controls and does not use Power System capability which is available at little penalty.

Concepts using the Power System in conjunction with either pallets or platform standoff radiators are adequate for most beta angle conditions. Both of these approaches require a Power System interface which would use the entire Power System capability. The choice using a platform radiator versus pallet radiators is a subsystem trade described in detail in Section 4.

3.3.2.4 Conclusions and Comments

A review of payload temperature requirements shows that nearly all payloads are satisfied by the Power System interface design of 60 to 110°F. Life Science and manned payloads will require a 40°F supply temperature which

will require a lower Power Module control temperature or a supplemental radiator.

Several alternate heat rejection options were examined to determine the desirability of using the Power System for heat rejection. The study showed that the more viable alternatives used the Power System capability in conjunction with either pallet radiators or platform radiators. Therefore, an interface is required with the Power System thermal control subsystem.

3.3.3 Power System Communications and Data Management Interfaces

3.3.3.1 Overall Requirements Summary

The SASP system concept provides for communications between experiments and the ground and between the SASP and the ground via the Power System, which communicates with the ground via the Tracking and Data Relay Satellite System (TDRSS). Bidirectional communication capability is required to allow commands and data to be sent from the ground to the SASP and its payloads (forward link) and to allow scientific and engineering data to be sent from SASP to the ground (return link). Forward data and commands are in digital form, whereas return link data may be digital or analog (including video). (Analog/video data may require conversion to digital to minimize impact on Power System and TDRSS communication links.)

In addition to these communications requirements, other data management capabilities, including command decoding, SASP data processing, experiment data processing, data storage, data multiplexing, and timing reference generation and distribution are required. Implementation of these requirements can be allocated to the Power System, the SASP, or the payloads in a variety of ways.

Typical data characteristics for single payloads are shown in Figure 3.3.3-1. A driving requirement is the return link peak data rate for payloads. The

distribution of these data rates is shown in Fiqure 3.3.3-2. Many payloads also require "continuous" return link data for purposes of rea` time interactive experiment control. Typical rates for this data is 50 Kbps or less per payload.

Digital Data Rate:	**<10 MBPS Peak (93% Payloads)** **120 MBPS Worst Case Peak Rates**
Video/Analog Data:	**< 500 kHz Analog** **1 or 2 Channels Slow-Scan TV** **Fast-Scan TV -- Some Payloads**
Acceptable Data Delay:	**Some Data (<50 KBPS) Real Time for Interactive Control — Delays of 1 Orbit to Several Hours OK for Bulk of Data**
Uplink Commands and Data:	**Low Rate (1 or 2 KBPS Peak)**
Timing Reference Requirement:	**10^{-5} sec Accuracy**

Figure 3.3.3-1 "Typical" Payload Data Characteristics

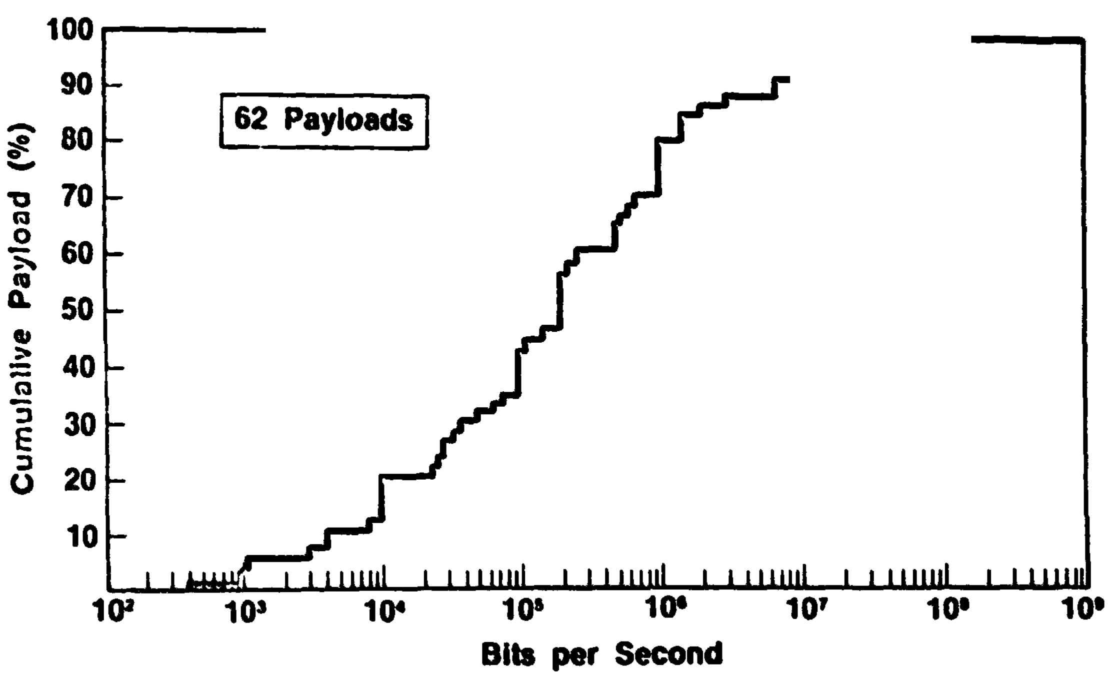


Figure 3.3.3-2 Percent of Payloads Having Data Rate $\leq$ X Bits Per Second

An important requirement of the communications system is that it be compatible with the TDRSS. Figure 3.3.3-3 summarizes the TDRSS capability in various operating modes and indicates that the appropriate mode for Power System/SASP appears to be the use of one or more dedicated Multiple Access (MA) channel plus a time-shared Single Access (SA) channel.

		RETURN LINK				
		PEAK RATE	BITS/ORBIT	CONTINUOUS RATE	FORWARD LINK PEAK RATE	INTERACTIVE CONTROL CAPABILITY
	SASP NEED	220×10^6	$10^{10} - 10^{11}$	$50 - 200 \times 10^3$	10×10^3	YES
TDRSS OPTIONS	MA ONLY	50×10^3	2.5×10^8	50×10^3	10×10^3	YES
	TIME SHARED SA	303×10^6	$(303 \times 10^6) \times T$*	–	300×10^3 OR 25×10^6	NO
	MA + TIME SHARED SA	303×10^6	$(2.5 \times 10^8) + (303 \times 10^6) \times T$	50×10^3	310×10^3 OR 25×10^6	YES
	DEDICATED SA	303×10^6	1.6×10^{12}	303×10^6	300×10^3 OR 25×10^6	YES
	DEDICATED TDRS**	606×10^6	2×10^{12}	606×10^6 (SMALLER % OF ORBIT)	600×10^3 OR 50×10^6	YES (PART OF ORBIT)

* T = SA TIME PER ORBIT ALLOCATED TO SASP

** THE DATA RATES SHOWN FOR THE DEDICATED TDRS OPTION ASSUME THAT COMPATIBLE GROUND DATA FACILITIES ARE AVAILABLE TO SASP DURING THE DATA DUMP TIME

Figure 3.3.3-3 TDRSS Utilization Options

3.3.3.2 Important Factors and Considerations

The communication data rate requirements for SASP are quite sensitive to the payload selection and grouping. As shown by Figure 3.3.3-2 payload return link data rates vary by orders of magnitude. It seems reasonable to expect that early SASP payload groups can consist of lower rate payloads than will the groups flown later. The Power System Communications and Data System must be designed eventually to accommodate rates and 200-300 Mbps. However, an initial capability to handle lower rates (on the order of 50 Mbps) may be acceptable if the capability to grow is included.

3.3.3.3 Work Accomplished

The Communication and Data Management capabilities of the Reference 25 kW Power System are summarized in Figure 3.3.3-4. These capabilities were compared to the overall requirements that were generated for SASP. Two major areas of concern were identified. The first concern is that the Reference Power System does not provide for experiment data storage. The implied operating mode of dumping experiment data in real-time is not consistent with TDRSS visibility and scheduling constraints. Other studies have indicated that TDRSS SA channels will be overloaded in the 1985-1990 time period. TDRSS scheduling opportunities for SASP can be improved by storing experiment data on a high rate recorder. This provides scheduling flexibility as well as a capability to concentrate a given amount of data transmission into a shorter TDRSS time slot.

Return Link Data Rate:	**223 MBPS Total (KSA)** **46 KBPS Total (MA)** **100 MBPS Max Per Payload Port**
Forward Link Data Rate:	**300 KBPS (SSA)** **10 KBPS (MA)** **1 KBPS (Command Decoding)**
Computational Capability:	**Support to Payloads Limited to Executive Level Control and Monitoring**
Multiplexing:	**16 Channels** **16 MBPS Max Per Channel** **48 MBPS Total**
Data Storage:	**Low Rate (Housekeeping) Data Only** **10^9 Bits Capacity**
Timing Reference:	**2 Parts in 10^8 Per Day**

Figure 3.3.3-4 REF Power System Data Capabilities

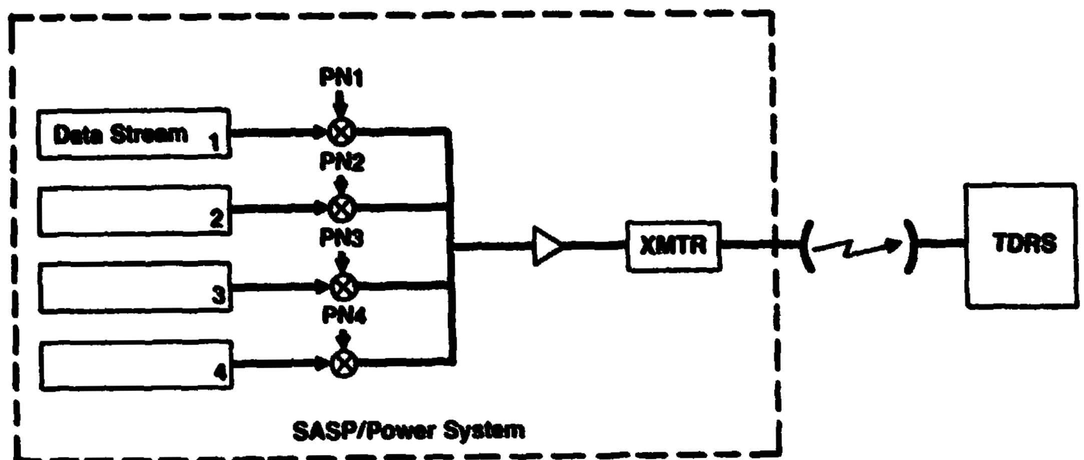
The desired recording capability could be provided by the payloads, by the SASP (for the Second Order Platform), or by the Power System. The recommended approach is to provide experiment data recording capability in the Power System equivalent to that provided by Spacelab and to supplement that capability with additional recording equipment for the Second Order Platform.

The second concern identified is that multiple payloads may simultaneously require a "continuous" return link capability of up to 50 Kbps. The Reference Power System provides a maximum MA return link data rate of 46 Kbps. The potential requirement (which may be as much as 200 Kbps continuous) can be met by using a dedicated TDRSS SA channel. This approach would be an inefficient use of an SA channel that will be much in demand by other users.

An alternate is to use two or more of the TDRSS MA channels on a dedicated basis. Figure 3.3.3-5 shows an approach to this that provides four (4) separate data streams of 50 Kbps or less that would occupy four (4) TDRSS MA channels. This approach, while apparently feasible, requires further study and analysis to assure that mutual interference (channel-to-channel), interference with other users, and Power System Effective Isotropic Radiated Power (EIRP) issues are resolved.

3.3.3.4 Conclusions and Comments

The Reference 25 kW Power System provides the basic communication and data management capabilities required to support the SASP and its payloads. Figure 3.3.3-6 lists some suggested capability expansions that would improve the overall utility of SASP to the payloads. The first two items on this list suggest that the Power System should provide the capability, or the capability to grow to, 300 Mbps KSA rates equal to the maximum TDRSS capability.



- Goal: Provide "Continuous" Data at Rates > 50 KBPS
- Each Data Stream is 50 KBPS or Less
- Each Data Stream has Different PN Code
- Technical Issues - (1) Mutual Interference
  (2) Power System EIRP
- Preliminary Indications Are That Up To 4 Data Streams of 50 KBPS Each Can Be Simultaneously Transmitted

Figure 3.3.3-5 Approach to TDRSS MA Usage >50 Kbps

- Increase KSA Link Capacity to 300 MBPS (TDRSS Max. Capacity)
- Increase Capacity at SASP Port to 300 MBPS (TDRSS Max. Capacity)
- Increase Continuous Channel Capacity to Approx 200 KBPS (For Improved Payload Interactive Control Capability)
- Provide Storage for Scientific Data (For First Order Platform)

Figure 3.3.3-6 Suggested Power System Capability Expansion

This is based on expected payload data rate growth and on the expectation that TDRSS SA channel time will be increasing in demand and that, consequently, there will be a premium placed on the high data rates.

The third and fourth items on this list were discussed previously.

3.3.4 Structural/Mechanical Systems Interfaces

A standard berthing latch should be used for Power System, Platform, and pallets. Such a concept is being developed by MDAC under a LaRC/JSC contract. Details are given below.

Power System - Berthing Latch Interface Requirements

- Object - Capture and structurally attach together two bodies in space; one which is being maneuvered by the RMS; the other is fixed to the Orbiter.
- Contact Velocities - Closing 0.1 ft/sec lateral and forward
  1 deg/sec pitch, roll and yaw
- Mismatch - Lateral six inches
  Angular pitch, roll and yaw 15 deg.
- Clear Access - A clear access opening 1.0 meter diameter shall be provided through the center of the Berthing Latch Interface Mechanism (BLIM).
- Envelope - The physical size limits of the passive half are defined by Figure 3.3.4-1. The physical size limits of the active half are defined by Figure 3.3.4-2.
- Loads - The BLIM shall be designed for a thrust load in both directions of 20,000 pounds and moments in pitch, roll, and yaw of 16,000 ft pounds. These loads shall be applied both in the capture mode and the rigidized mode.

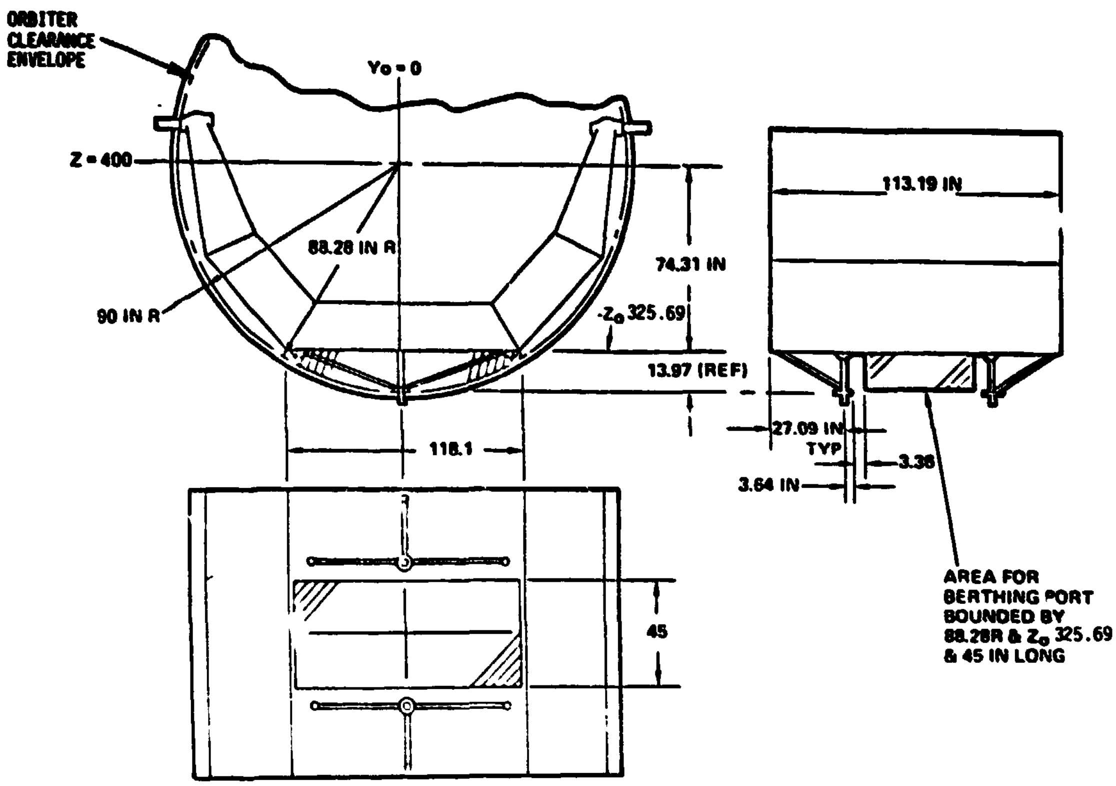


Figure 3.3.4-1 Pallet Berthing Port Envelope Volume

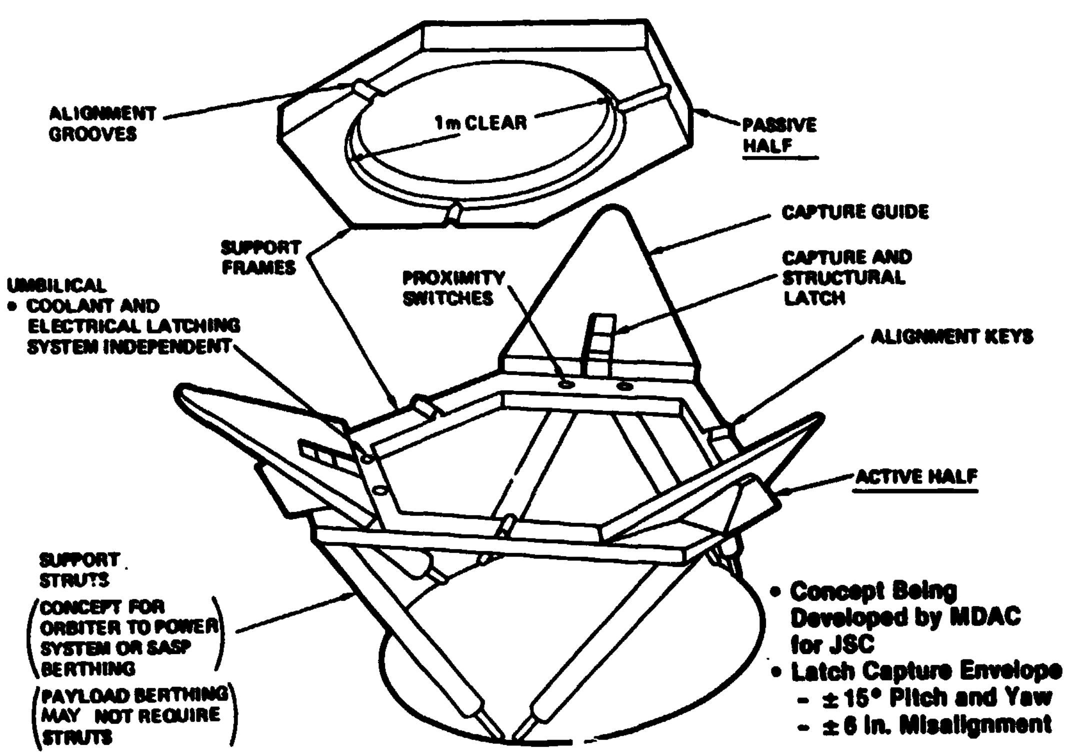


Figure 3.3.4-2 Hexagonal Frame Berthing Latch Interface (LaRC/JSC/LSST Study)

- Alignment - After mating and rigidizing the active and passive halves of the BLIM, the angular alignment in pitch, roll, and yaw of one half relative to the other shall be within $\pm$ 1.32 arc min.

- Capture Latches - The capture latches shall be designed for simultaneous operation, i.e., a single capture latch of a multiple array of latches shall not provide a structural tie between the two halves of the BLIM until all latches are engaged.

- Umbilicals - The BLIM shall provide mounting provisions for two fixed umbilical plates on the passive side of the mechanism and two actuated plates on the active side of the mechanism.

- Active Ports - Houses latching mechanism umbilicals, and requires power.
  + and -Y ports (for payload).
  +Z port (for payload and temporary storage)
  +X port (for trail arm payloads)
  -X port (for propulsion unit)

- Passive Ports - No power required.
  -Z port (The Orbiter houses latching mechanisms and provides power.)
  The PS shall provide two offset 0 $\pm$ 90° gimbals that rotate about both the Orbiter and PS docking port centerlines. These offset gimbals provide RMS access to the Propulsion Module and the +Y Docking Port.

- Control and Feedback - The mechanism shall contain switches to operate indicator circuits within the Orbiter control station. These circuits shall indicate the status of the BLIM for actions such as:
  - Ready to berth
  - Capture complete
  - Structure latches secure

- Redundancy - All drive mechanisms and latches shall incorporate redundant power sources arranged so that any single failure will still allow operation of the other.
- Manual Override - All drive mechanisms shall permit them to be manually operated by an EVA astronaut in the event of failure of the power sources.
- Operating Power - The active half of the BLIM shall operate using 28-33 volt DC electrical power. The peak electrical power for operation shall not exceed 1000 watts. The steady state electrical power either mated or unmated shall be zero watts.

3.3.4.1 Work Accomplished

The berthing port illustrated in Figure 3.3.4-3 is similar to the concept being developed by MDAC for JSC. The goal was to have all of the berthing ports interchangeable. The envelope of the berthing latches were determined by the pallet-to-Orbiter clearance and pallet-to-SASP relationship. The capture envelope was the result of all the various berthing and docking system criteria now in use and the limitation of the RMS. It is planned to have shock absorbing features on the Orbiter to Power System and SASP interfaces to reduce the berthing shock loads. The pallet to SASP or Power System interface probably will not require shock attenuation devices, since the RMS is relatively flexible and has its torque limitations. The electrical and coolant umbilical will be on separate latching devices. The system is designed to capture and berth any payload within $\pm 15°$ pitch and yaw and +6" misalignment.

We are presently designing a prototype mockup berthing latching system under contract with LaRC/JSC/LSST and will have simulation testing utilizing the RMS simulator and air bearing floor. We should accumulate important data for the design of the future berthing ports.

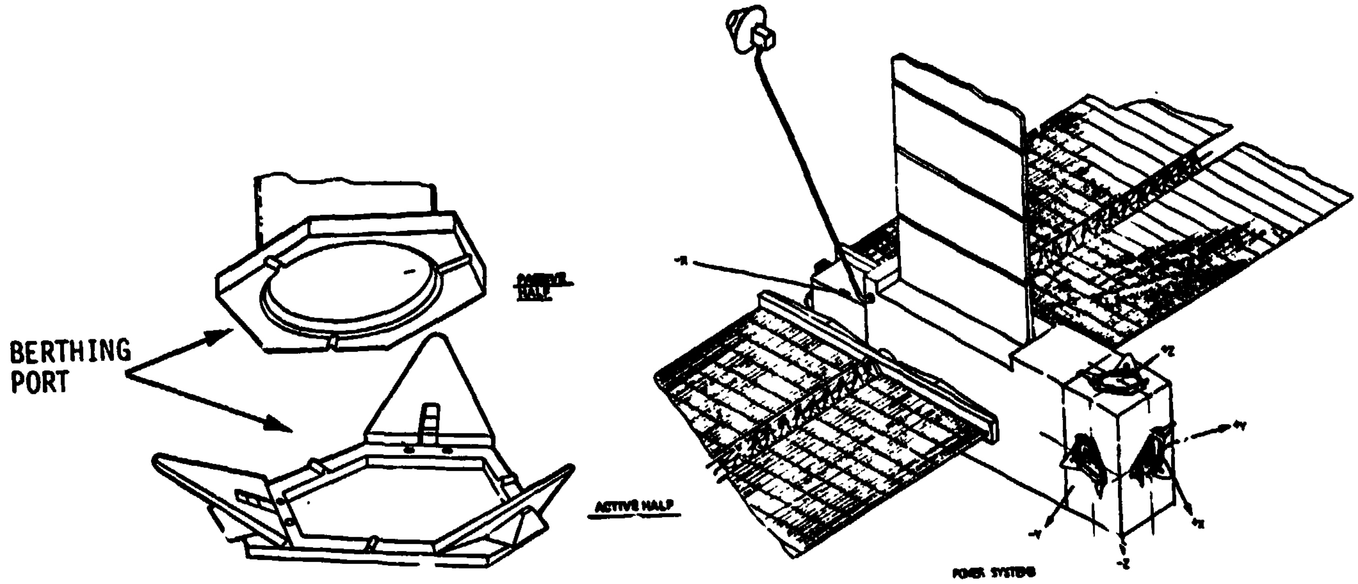


Figure 3.3.4-3 Power System Mechanical System Interfaces

3.3.4.2 Conclusions and Comments

The berthing ports on the Power System were made active except for the Orbiter berthing port which is passive. An active port is one where the latching mechanism is located and has power, data, and coolant. The passive port is the inert side which does not have power until the umbilicals are matched. The Orbiter berthing port was made passive, since the active side is on the Orbiter which is used for other applications than berthing to the Power System. The active half was located on the remainder of the berthing ports because the experiments and propulsion system and other equipment berthing to these ports are inert and do not have power.

Section 4
SUBSYSTEM TRADES AND ANALYSIS
(Task 4)

Table 4-1 lists the major Platform subsystem trades performed durin, the study. This section presents these trades and analyses which led to the selection of design approaches for the Platform. See Section 10, Conclusions and Recommendations, for a summary list of trades and results.

4.1 STRUCTURES AND MATERIALS TRADES

This subsection contains the trade studies conducted for selecting the optimum structures and material concept for the SASP. The following work was accomplished in this task.

- Structural module optimization completed:
  - five fixed truss configurations evaluated
  - two deployable truss configurations evaluated
  - truss stiffness and complexity factors determined
  - truss conf.gurations selected for fixed and deployable trusses
- Material selection trade completed:
  - aluminum, titanium, and graphite/epoxy evaluated
  - factors considered include, radiation resistance, coefficient of thermal expansion stability, thermal distortion characteristics, specific stiffness, elevated temperature resistance, dimensional accuracy, and manufacturing complexity.

1st Order configuration	
2 vs 3 vs 4 payload berthing ports	3 active payload berthing ports (1 park)
Fixed vs moveable berthing ports	4 position clocked berthing ports
Bottom vs side or end pallet mounts	Bottom mounted pallets
Standoff mini-arms vs direct-to-power system pallet mounting	Standoff mini-arms
Fixed vs scheduleable vehicle orientation	Orientation variable
2nd Order configuration	
Basic shape and compaction (many concepts evaluated)	Folding cross-arms with fixed standoff structure (T bar)
2 vs 3 arms	Payload/program dependent
Degree of arm rotational capability	±180 degree full length arms 360 degree mini-trail arm
Payload berth separation	13.2 m
PS standoff separation	13.4 m
Fixed vs scheduleable vehicle orientation	Variable orientation
Number of primary berthing ports	5 to 9 (program dependent)
Structural elements and materials	
Fixed truss configurations	Square X rectangular box (sing diag truss)
Deployable truss configurations	Telefold (cable drive)
Truss material	Graphite/epoxy (alum. if covered by radiator)
Attitude control	
Concept approach	PS control (more magnetic torquers requested)
Momentum dump considerations	Options identified orientation and payload dependent
Preliminary modal analysis	Designed in structural damping recommended to improve critical system stability
External disturbance analysis	Methods identified to reduce disturbances
Open loop AGS pointing system disturbance response	Pointing performance potentially much better than orbiter closed loop analysis needed to assess ultimate performance
Thermal/structural response	Acceleration levels and line of sight disturbances identified - potentially not significant impact
Example payload group evaluation	CMG desaturation every 4 orbits less with orientation skewing
Communications and data management	
Centralized versus distributed payload data processing	Distributed
Payload data storage on power system, platform or pallet	Power system for 1st order platform, supplement by platform system for 2nd order
Multiplexing on power system versus platform	Power system for 1st order platform, supplement by platform system for 2nd order
Berthing equipment	
1st order platform berthing system	Reference power system berthing unit with 1st order platform berthing adaptr
2nd order platform berthing system	Reference power system orbiter berthing unit with telescoping boom
Alternate payload carrier	
Many evaluated	Ring-type carrier appears advantageous
Thermal control	
Centralized versus pallet radiator	Centralized
Loop arrangements - parallel or series	Parallel
Payload interface options	2 loops with direct fluid interface
Centralized radiator-dual loop alternates	Separate panels optimum
Centralized radiator flow options comparison	Panels in series (4 passes per panel is optimum)
Payload cryogenics	
Cryogenic resupply interface trade	Passive cryogenic cooling requires on orbit fluid transfer
"Common" platform mounted tank size	1.5M tank diameter is optimum
Tank replacement versus tank refull	Tank replacement
Tank refill analysis	Refill from supercritical source or large amounts not feasible
Replacement tank location trade	Payload or accessory pallet location optimum
Power distribution	
Platform power circuit protection/switching options trade	Remote control circuit breaker preferred
Cross-arm power distribution option trade	Radial circuits from support module distributors
Peak/pulse power loads options trade	Power system capability used up to ~~[illegible]~~ 20 kw at cross-arm berthing ports, payload provides above this (25 kw available at ±Y and X ports of power system and at platform trail arm berth)
Mechanisms	
2nd order platform arm design	Fixed truss with deployable extensions
Rotating joint options	Two-stage in-line utility barrels, EVA replaceable
2nd order platform tolerance	All concepts had relatively small error
2nd order expandable structure service routing concepts	Loop service lines and cables
Support module concept options	Isogrid box with elbow hinges for arms
Pallet access	
1st order (dual hub adapter or multiple dock)	Dual hub adapter
2nd order (dual hub/telescopic, multiple dock or relocated rms)	Dual hub/telescopic

Table 4-1 Trade or Analysis and Results

	Power Module	Support Module	Platform Arms		Payload Carrier		Orbital Reboost/ Transfer Propulsion
Capacity	25 KW	Unmanned Payloads Only	Mission Model Satisfaction: 100%		1 Pallet Equivalent		~40 KM Reboost
	15 KW	Manned Payloads Only	85%		2 Pallet Equivalent Set		~200 KM Transfer
		Hybrid of Above	70%		3 Pallet Equivalent Set		Hybrid of Above
Type	Complete Utility Service to Platforms	Unmanned Support Module	Erectable (Docked)	Pre-Fab	Spacelab Pallets	End Mounted	Teleoperator
	Partial Utility Service to Platforms	Manned Support Module	Hybrid Erectable Deployable	Pre-Fold	Ring or Pancake Pallets	Side-Saddle Mounted	Orbiter
	Integrated Power/Support Module			Telescopic	Isogrid Pallets	Base Mounted	New Propulsion Module: ● Unit Tank ● Modular Tanks
	Double Integrated Power/Support/Airlock Module				Other		Combination
	Power and Attitude Control Only to Platforms	Integrated Support Module and Deployable Arms					
Services	Power	Power Distributuion	Supplem Radiator ● Wall Mtg ● Deployable		Supplem Radiator ● Face Mounted ● Deployable		~3000 lb Propellant System
	Thermal	Thermal Mgt.	Super Coolant		Super Coolant		~8000 lb Propellant System With Long Range Remote Control
	Commun./ Data	Supplem. Comm/Data	Supplemental Pointing Reference		Supplemental Pointing Reference		Hybrid
	Attitude Control	Supplem. Att. Cont.	Rot. Frt. Jt.		Supplemental Data Service		
	Docking Ports	Docking Ports	Del. Rot. End Jt.				
	Rotating Joints	Rotating Joints					

Table 4-1a Platform Configuration Element Options

The following conclusions resulted from this task:

1. Truss configuration 1B-A is optimum for deployable truss and 1B for fixed truss.
2. Aluminum, titanium, and graphite/epoxy were evaluated for the structural material and graphite/epoxy was selected.

Subsection 4.1.1 summarizes the design parameters and requirements. Subsection 4.1.2 presents the structural module optimization analysis. Five fixed truss and two deployable truss structural module configurations were evaluated. The fixed truss concepts have all members fixed relative to one another while the deployable trusses can be folded or compacted for launch and then deployed on orbit. Subsection 4.1.3 contains the material selection trade study conducted for aluminum, titanium, and graphite/epoxy.

4.1.1 Design Parameters and Requirements

Figure 4.1-1 summarizes the SASP structures and materials design parameters and requirements. As it can be seen from this figure, the SASP structure should have a life of 10 years, minimum distortion (relatively high accuracy and stability), and require existing structures technology.

4.1.2 Structural Module Optimization

In order to select the structural concept that provides the required stiffness (minimum structural frequency = .1 Hz, see Section 5.4.1) with minimum complexity, a structural module optimization study was conducted. The study considered five fixed and two deployable truss module configurations as shown in Figure 4.1.2-1. The module configurations were rated for absolute stiffness, specific stiffness (stiffness per unit weight), stiffness to complexity ratio, and absolute complexity. Graphite/epoxy with a modulus of $E=20 \times 10^6$ psi

CONFIGURATION –	MODULAR DESIGN, GROWTH CAPABILITY
MISSION DURATION –	5 TO 10 YEARS WITH PERIODIC SERVICE
G LEVELS –	NORMAL FREE-FLIGHT MANEUVER – 10^{-3} TO 10^{-5} G REBOOST (2.7 m/sec) – ~ 0.001G SHUTTLE BERTHING – < 0.001 G SHUTTLE-MATED RCS MANEUVER – ~ 0.04G
STRUCTURE –	LOW TECHNOLOGY, EARLY AVAILABILITY
POINTING/STABILITY –	POINTING ERROR < 2 DEGREES WITHOUT POINTING ASSIST POINTING STABILITY < 6 ARC MIN
ALTITUDE –	LOW EARTH ORBIT (435 km NOMINAL) • DETERMINES RADIATION LEVELS • INFLUENCES ΔT PATTERNS
INCLINATION –	VARIABLE (28 DEG, 57 DEG, 70 DEG, 90 DEG, SUN SYNCHRONOUS) • DETERMINES RADIATION LEVELS • INFLUENCES ΔT PATTERNS

Figure 4.1-1 SASP Design Parameters and Requirements

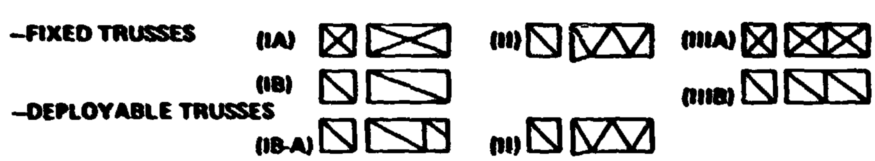
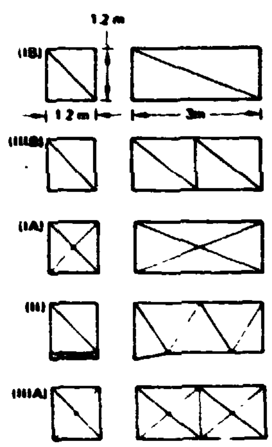


Figure 4.1.2-1 Fixed and Deployable Truss Structural Modules Evaluated

was assumed as the material. Other materials were not considered here since the main objective was to determine the relative overall geometric complexity and stiffness of the candidate structural modules.

4.1.2.1 Fixed Truss Property Summary

The fixed truss structural module basic dimensions, weight, complexity factor (NIM), effective axial area (A_{EFF}), effective shear stiffness moment of inertia (IS_{EFF}), effective bending stiffness moment of inertia (IB_{EFF}), and effective torsional stiffness term (GJ_{EFF}) are summarized in Figure 4.1.2-2. These terms are determined by the method given in Reference 4.1.



	WT (LB)[3]	NIM[4]	A_{EFF} (in.^{2})	$I_{S_{EFF}}$ (in^4)	f_{B_1}[7] (Hz)	$I_{B_{EFF}}$ (in^4)	GJ_{EFF} X 10^{-10} (lb-in.^{2})	f_{t_1} (Hz)[8]
(IB)	82 (0.69 lb/in.)	28	4.04	668	0.182	2,251	0.324	0.309
(IIIB)	100 (0.92 lb/in.)	52	4.03	1,113	0.235	2,243	0.868	0.506
(IA)	123 (1.04 lb/in.)	56	10.3	1,654	0.286	3,986	1.149	0.582
(II)	141 (1.19 lb/in.)	98	4.07	1,525 1,285[6]	0.275 0.260	2,437 2,278[6]	1.312	0.622
(IIIA)	166 (1.40 lb/in.)	112	7.75	2,112	0.324	3,086	2.64	0.88

NOTES
(1) ALL MEMBER CROSS SECTIONAL AREAS = 1 in.^{2}
(2) JOINT WEIGHT ESTIMATED BY 3 in^3 X NIM X (0.0523 pci)
(3) WEIGHT INCLUDES ESTIMATE FOR JOINTS
(4) NIM = NUMBER OF INTERSECTING MEMBERS
(5) MATERIAL IS GRAPHITE/EPOXY
(6) TRANSVERSE STIFFNESS
(7) 1st BENDING FREQUENCY } L = 54 FT } CANTILEVER BEAM
(8) 1st TORSIONAL FREQUENCY } W = 43,764 LB

Figure 4.1.2-2 Structural Module Property Summary (Fixed Truss)

The first bending and torsional natural frequencies of the platform arms (cantilever beams) are also summarized. These natural frequencies are conservatively based upon the effective shear stiffness moment of inertia term (IS_{EFF}), an arm length of 54 feet (16.5 m), a discrete weight of 43,764 lb (19,848 Kg) and neglect the arm distributed weight. A review of the candidate platform loadings indicates this to be a worse case condition. It is seen that all frequencies satisfy the requirement of $f_n \geq .1$ Hz.

4.1.2.2 Deployable Truss Complexity Factor Determination

Two deployable truss module configurations were evaluated for their complexity and a complexity factor was developed for each. Configuration II was evaluated since it represents MDAC's scaled down version of the MSFC deployable arm concept. Configuration (IB) was selected based upon the results obtained in the fixed truss analysis. Due to geometry constraints of folding the longerons and staying within the overall cross-sectional envelope, the (IB) module length had to be shortened for the deployable case. Hence, this module was identified as (IB-A). As seen on Figure 4.1.2-3, it will take 1-1/2 (IB-A) modules to cover the same length as a configuration (II) module.

Module	WT (LB)[1]	NMJ[2]	NIFM[3]	COMPLEXITY FACTOR Σ NMJ + NIFM
(IB-A) 	82[1]	54[4]	18	72
(II) 	141[1]	43[5]	95	138

(1) REFERENCE ONLY - WEIGHT SHOWN IS FOR FIXED-TRUSS MODULE
(2) NUMBER OF MOVING JOINTS   EXCLUDES ACTUATING MECHANISMS
(3) NUMBER OF INTERSECTING FIXED MEMBERS
(4) 42 ROTATING JOINTS, 12 SLIDING JOINTS
(5) ALL MOVING JOINTS ROTATE

Figure 4.1.2-3 Deployable Truss Structural Module Complexity Factor Determination

The complexity factor for the modules was defined as the sum of the number of moving joints (NMJ) and the number of intersecting fixed members (NIFM). In the case of the (IB-A) module the number of moving joints consists of 42 rotating joints plus 12 sliding joints. In the case of the (II) module, all 43 moving joints rotate.

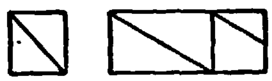
The module (IB-A) complexity is 72 and the module (II) complexity factor is 138.

4.1.2.3 Deployable Truss Stiffness/Complexity Rating Evaluation

The detailed stiffness/complexity total rating evaluations for the deployable truss candidate modules are summarized on Figure 4.1.2-4. These ratings were developed in the same manner and with respect to the same rating scale as for the fixed truss modules. Hence, since the deployable trusses are more complex than the fixed trusses, their total rating numbers are lower. It is seen that module (IB-A) has a better total rating than module (II).

4.1.2.4 Fixed Truss Optimization Summary

Detailed evaluation of absolute stiffness, specific stiffness and stiffness/complexity are given in Reference 4.1.

	CF (1)	I_S (2)	$\frac{I_S}{CF}$	RATING	I_B (2)	$\frac{I_B}{CF}$	RATING	GJ (3)	$\frac{GJ}{CF}$	RATING	TOTAL RATING
	SHEAR STIFFNESS				BENDING STIFFNESS			TORSIONAL STIFFNESS			
(IB-A) 	72	917 (4)	12.7	4.2	2,247 (4)	31.2	3.6	0.628 (4)	0.0087	3.8	11.6
(III) 	130	1.525	11.1	3.0	2.437	17.7	2.0	1.312	0.0095	4.1	9.9
		1.265 (5)	9.2	3.1	2,279 (5)	18.5	1.9				9.1 (5)

(1) COMPLEXITY FACTOR
(2) $IN.^4$
(3) $LB\text{-}IN.^2 \times 10^{-10}$
(4) ESTIMATED USING CONFIGURATION IB AND IIIB DATA
(5) TRANSVERSE STIFFNESS

Figure 4.1.2-4 Deployable Truss Structural Module Stiffness/Complexity Rating Evaluation

Figure 4.1.2-5 summarizes the fixed truss absolute stiffness, specific stiffness and stiffness/complexity ratings of the five candidate module configurations. It is seen that module (IIIA) has the best absolute stiffness total rating while module (IA) has the best specific stiffness and stiffness/complexity total rating. On this basis, configuration (IA) could be considered the optimum structural module configuration. However, even though module (IB) has the lowest absolute and specific stiffness total ratings, preliminary conservative calculations show that the stiffness provided is sufficient to satisfy the $f_n \geq .1$ Hz requirement for the SASP Platform. This consideration, combined with configuration (IB)'s second best rating on a stiffness to complexity basis and the fact that configuration (IB) is least complex having half or fewer intersecting joints, resulted in the selection of configuration (IB) as the optimum structural model configuration for the SASP structure. In the 2nd order extended configuration, the fixed truss structure is applicable to the standoff arm between the Power Module and Platform Support Module and the crossarm structure from the pivot outboard to the first experiment port.

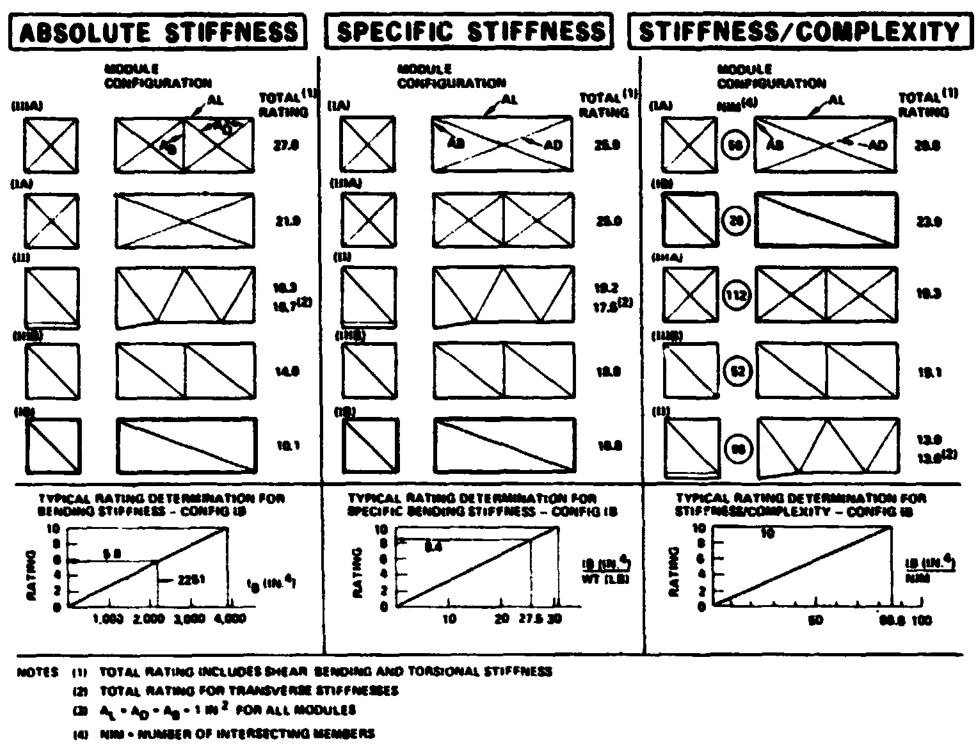


Figure 4.1.2-5 Fixed Truss Structural Module Optimization Summary

4.1.2.5 Deployable Truss Optimization Summary

The stiffness/complexity total ratings for the deployable truss candidate modules are summarized on Figure 4.1.2-6. It is seen that module (IB-A) has a better total rating than module (II). Since the stiffness of module (IB-A) is sufficient to meet the natural frequency requirement of $f_n \geq .1$ Hz, this module is chosen as the deployable module concept for the SASP structure. The deployable IB-A Module applies to the 2nd Order Extended SASP cross-arm structure outboard of the two inboard experiment ports.

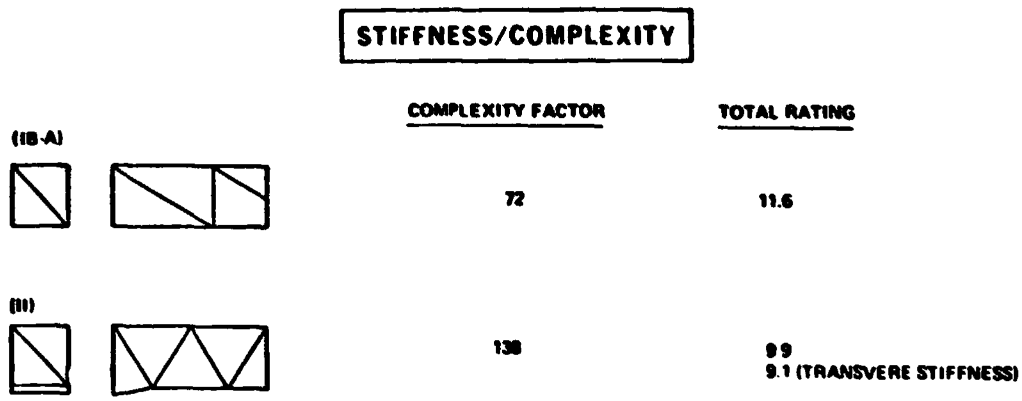


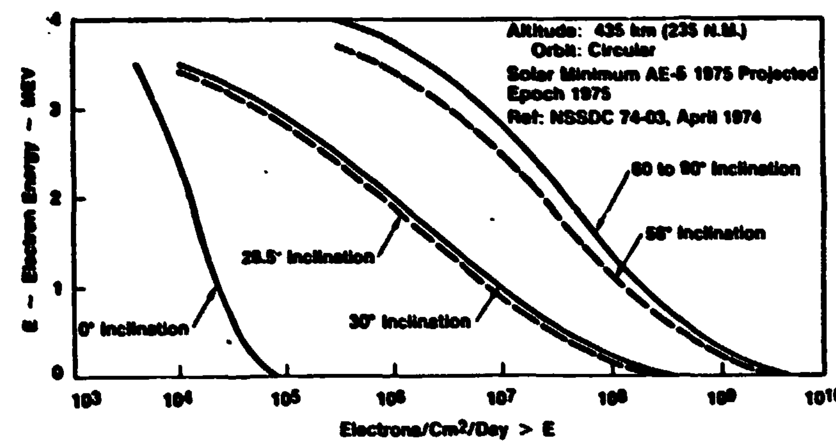
Figure 4.1.2-6 Deployable Truss Structural Module Optimization Summary

4.1.3 Material Selection Trade

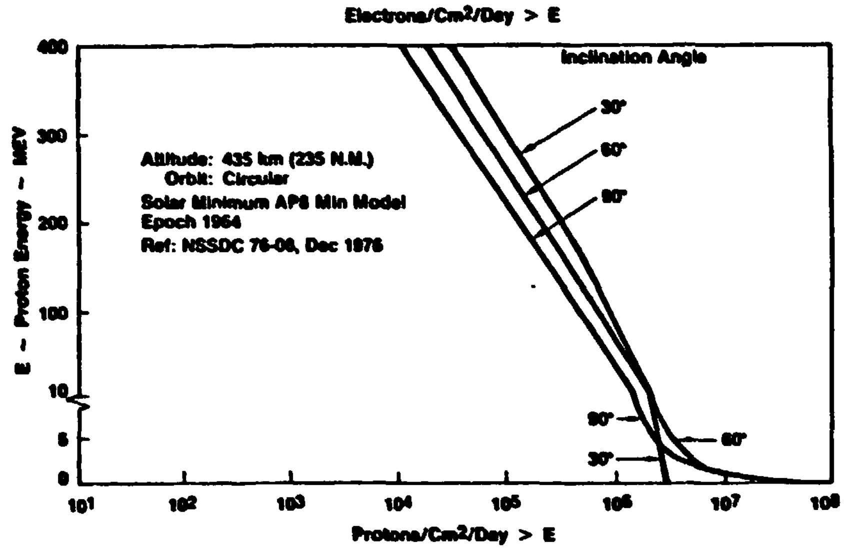
It is well established that aluminum and titanium have excellent radiation resistance and coefficient of expansion (CTE) stability. Since this is not the case for graphite/epoxy, and so a preliminary evaluation of these factors was conducted for this material.

4.1.3.1 Effect of Natural Trapped Radiation on Graphite/Epoxy Structural Properties

Figure 4.1.3-1a presents the natural trapped proton radiation environment for a 435 km circular orbit. The data are based on the solar minimum model (AE-5 1975 projected) with an epoch of 1975 given in Reference 4-2. Electron fluence (electrons/cm^2/day) for electron energy levels greater than E is plotted against electron energy level E for the noted orbital inclinations. Figure 4.1.3-1b presents the natural trapped proton radiation environment for a 435 km circular orbit. The data are based for the most part on the solar minimum period of 1964 and, therefore, this model is designated as AP8MIN, epoch 1964. The data are extracted from Reference 4.3. Proton fluence (protons/cm^2/day) for proton energy levels greater than E is plotted against proton energy level E for the noted orbital inclination angles.



(a)
Trapped
Electrons



(b)
Trapped
Protons

Figures 4.1.3-1a & 4.1.3-1b SASP Natural Radiation Environment
(Integral Fluence/Day)

Using the trapped electron and proton radiation environments presented above, the radiation dose to the SASP structure was computed using the MDAC CHARGE computer program for a SASP graphite/epoxy strut with a typical wall thickness of .125 in. The calculations were performed for an orbital inclination of 97°. The combined electron and proton dose computed for the 97° inclination is representative of the combined electron and proton dose at an inclination of 56° and is conservative for the 28.5° inclination. The computed dose profile is shown on the left side of Figure 4.1.3-1c.

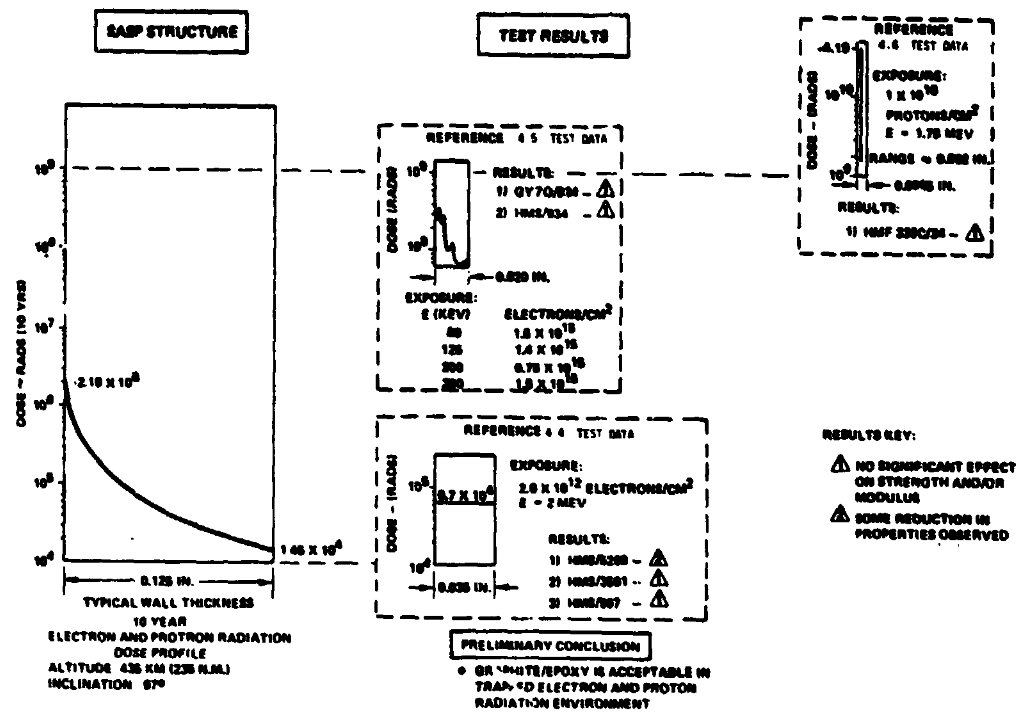


Figure 4.1.3-1c Effect of Radiation on Graphite/Epoxy Properties

Also shown on the right side of Figure 4.1.3-1c are test results obtained from References 4.4, 4.5, and 4.6. The test data are applicable to test specimens with the noted thicknesses, materials, and electron and proton fluences. The MDAC CHARGE program was used to compute the radiation dose to these specimens and the specimen dose profiles in rads are also shown on the figure.

A preliminary conclusion from this analysis indicates that the graphite/epoxy material properties should not be degraded by the trapped electron and proton environment over the 10 year life of the Platform.

4.1.3.2 Coefficient of Thermal Expansion (CTE) Stability of Graphite/Epoxy

It is well known that some graphite/epoxy laminates, initially designed for nominally zero CTE, deviate from the initial CTE value when subjected to thermal cycling. The magnitude of the change in CTE, if any, depends upon several factors including resin and fiber materials used, resin cure temperature,

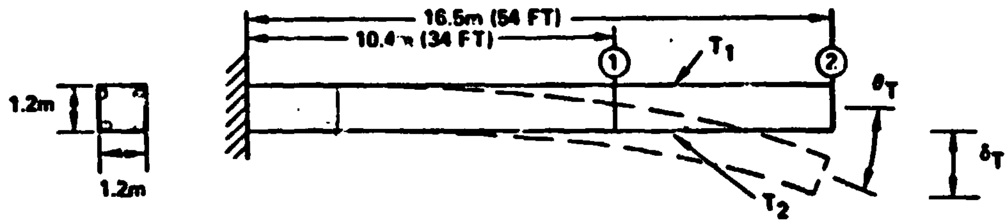
laminate lay-up, thermal excusion range (ΔT) and minimum temperature experienced. The variation in the CTE, if any, is due to micro-cracking of the resin due to translaminar stress relief (TSR) [Reference (4.7)], which is initiated at a critical low temperature limit. The data in Reference (4.7) indicates that TSR does not occur for certain composites such as HY-E 1530 down to -150°F. More complex laminate systems have lower critical limits down to -320°F.

For 10 years in low earth orbit 56,500 thermal cycles will be experienced. The maximum temperature extremes expected for a SASP graphite/epoxy strut are shown on Figures 5.4.3-1 and 5.4.3-3. The actual environment will consist of a complex combination of lesser conditions up to the temperature extremes shown. Since the minimum predicted SASP structural temperature of -127°F is above the critical lower limit of -150°F, it can be concluded that the SASP nominally zero CTE structure will be dimensionally stable for the low earth orbit environment.

4.1.3.3 Cross Arm Structural Distortion Estimates

A preliminary estimate of the platform arm thermal distortion was made for arms constructed of graphite/epoxy, titanium, and aluminum. The assumed arm geometry and distortion results are on Figure 4.1.3-3. The calculation assumes a ΔT = 100°F between upper and lower longerons and the modulus of elasticity (E) and coefficient of thermal expansion (CTE) used in the computations are listed for the three candidate materials.

It can be seen that with a graphite/epoxy structure, thermal distortions are more than two orders of magnitude less than for an aluminum structure. The maximum rotation at station 2 for an aluminum structure is slightly more than a degree. These distortions are to be considered as reference information only since they are based upon an idealization of the expected real thermal gradient



$\Delta T = T_1 - T_2 = 100°F$

MATERIAL	PROPERTY		STATION 1		STATION 2	
	EX10^{-6} PSI	$\alpha \times 10^6$ IN./IN./°F	δ_T (IN.)	θ_T (SEC)	δ_T (IN.)	θ_T (SEC)
GR/EP	20	0.1	0.018	17.8	0.044	28.3
TITANIUM	16	5	0.90	890	2.2	1,415
ALUMINUM	10	13	2.34	2314	5.72	3,679

Figure 4.1.3-3 Preliminary Estimate of Cross Arm Thermal Distortion

patterns and an assumed reference ΔT = 100°F. A more detailed thermal evaluation is required to predict the actual thermal distortions but the data shown are considered to be indicative of the relative thermal distortion characteristics of the three materials shown.

4.1.3.4 Material Selection Summary

Figure 4.1.3-4 summarizes the factors considered in the evaluation of the three candidate materials; (1) graphite/epoxy, (2) aluminum, and (3) titanium. Graphite/epoxy with nominally zero CTE ($0 \pm .1 \times 10^{-6}$ in/in/°F) was selected as the optimum material because of its minimal thermal distortion characteristics, outstanding specific stiffness at room and elevated temperature, excellent dimensional accuracy and acceptable CTE stability, and radiation resistance determined from analysis. Although the complexity of manufacturing is considered greatest for graphite/epoxy, the technological data base is significant and no major obstacles are expected.

Property	SELECTED Graphite-Epoxy	Aluminum 6061-T6	Titanium 6A1-4V
Stiffness/Weight (E/P)	300×10^6	100×10^6	100×10^6
(CTE) Coefficient of Thermal Expansion (In/In/°F)	$0 \pm 0.1 \times 10^{-6}$	13×10^{-6}	5×10^{-6}
Elevated Temperature Resistance (% E At 350°F)	0.93	0.92	0.91
Radiation Resistance	Acceptable	Excellent	Excellent
Dimensional Accuracy	Excellent	Exceller	Excellent
CTE Stability	Acceptable	Excellent	Excellent
Manufacturing Complexity (1 = Best)	3	1	2

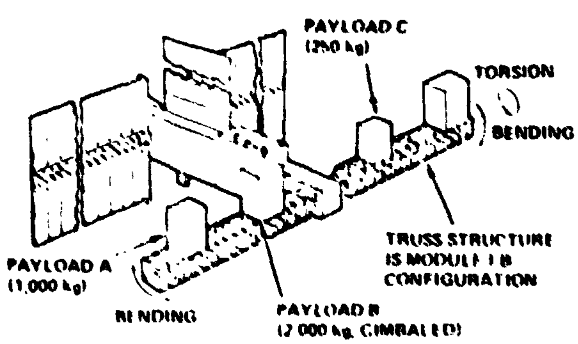
Figure 4.1.3-4 Structural Material Selection

4.2 ATTITUDE CONTROL SUBSYSTEM

A high level summary of the trades and analyses effort for the ACS is presented in Figure 4.2-1 and is reported on in this section. These trades and analyses relate to the dynamics considerations presented in Section 2.4 on Configuration Drivers.

4.2.1 Requirements Summary

The SASP attitude control requirements include experiment pointing and maintenance of a low-g environment. A capability to accommodate simultaneous multiple payload viewing is highly desirable. The pointing requirement includes initialization for target acquisition for payloads with their own pointing systems and continuous pointing during experiment operation for pointing payloads without their own pointing systems. The SASP must maintain some level of pointing performance during payload operations even for payloads with their own pointing system because the payload pointing systems have a



TRADES AND ANALYSES PERFORMED

- ACS Approach
- Momentum Dump Options
- Preliminary Bending Model
- External Disturbance Response
- Open Loop AGS Response
- Thermo/Structure Response
- A-10 Attitude Evaluation

RECOMMENDATIONS

- PS Control (More Magnetic Torque May Be Required)
- SASP · 180 Rotating Arms
- Experiment Pointing Systems on Payload Carrier
- Image Motion Compensation in Payload
- Relative Alignment Sensing (Possible)
- PS/SASP Use of Payload Sensors

REQUIREMENTS

- Pointing Accuracies and Stabilities From None to Less Than One Arc Sec
- Low-G Environment to 10^{-5} G's
- Solar, Celestial, Earth and Simultaneous Viewing Targets

Figure 4.2-1 SASP Attitude Control Subsystem

finite capability to isolate the payload from the SASP. The payload pointing requirements (Figures 2.1.5-1, 4.2.1-1, 4.2.1-2) range from none to 0.1 arc sec accuracy and 0.005 arc sec stability. The most stringent pointing requirements cannot reasonably be met with a structure as large as the PS/SASP vehicle and auxiliary payload pointing systems are required. The SASP pointing performance related requirements will ultimately be defined by the performance of auxiliary pointing systems.

4.2.2 Important Factors and Considerations

The ACS design is highly influenced by the presence of the Power System. This is because control is provided by the PS for the SASP/PS configuration. The adequacy of PS capability and possible options for SASP improvement are key issues. Gravity gradient, aerodynamic, and other external disturbances must be considered. Disturbances generated by both SASP elements and the PS can also cause significant perturbations. Structural shape in terms of the moment of inertia dyadic and the range of deviation between the principal

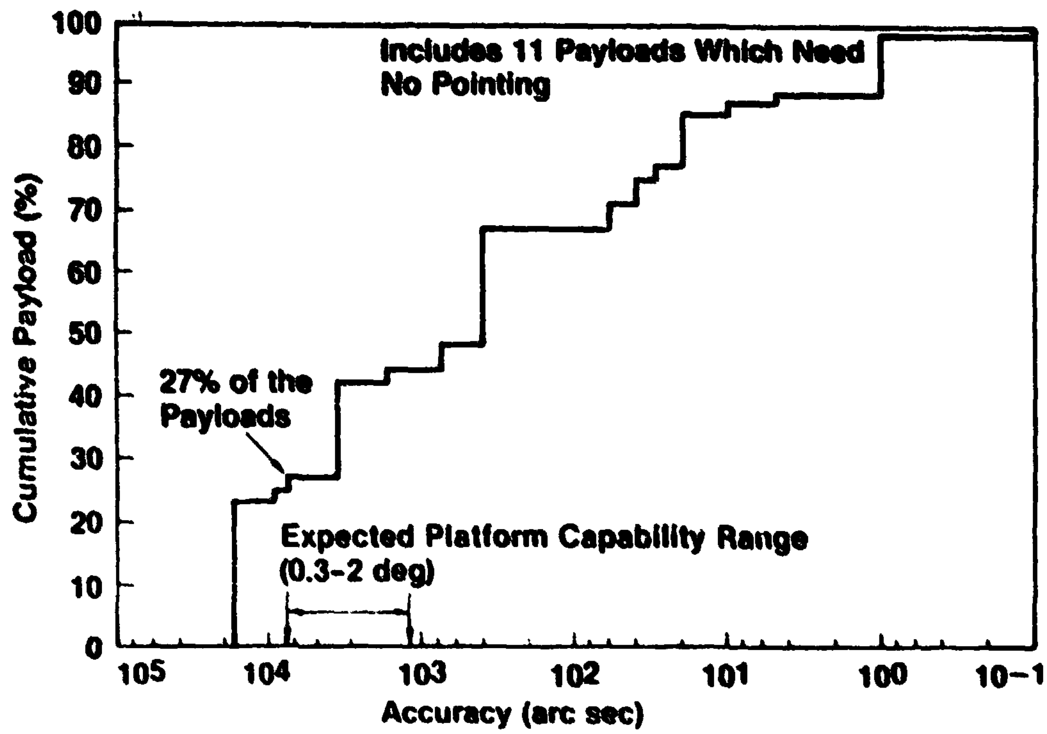


Figure 4.2.1-1 Pointing Accuracy Requirements

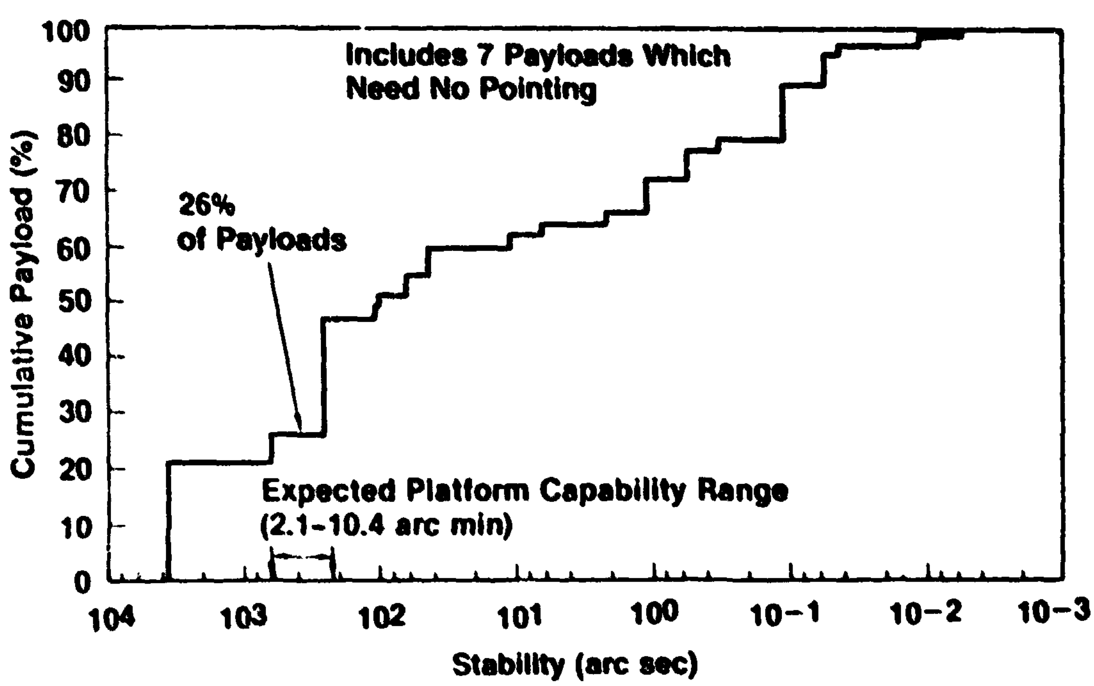


Figure 4.2.1-2 Pointing Stability Requirements

and geometric axes are important factors. As stated above, the ability of the Platform to accommodate fine pointing experiments depends on the capability of experiment pointing systems to operate in the SASP dynamic environment.

4.2.3 Work Accomplished

Attitude control related areas addressed during this study included:

- Payload requirements
- SASP attitude control options
- Disturbance identifications
- Aero and gravity gradient disturbances (momentum management)
- Structural dynamic modeling
- Auxiliary pointing system modeling
- Thermal-structural dynamics interactions
- Acceleration and pointing performance at the payload

These areas are reported on in detail in the paragraphs below.

4.2.4 Conclusions and Comments

Power System ACS will be employed to control the SASP/PS configuration. It appears that more magnetic torquers should be added to either SASP or the PS. Rotating arms ($\pm 180°$) will provide custom pointing. Fine pointing will require experiment pointing systems; these will also produce greater potential FOV capability and resolve many conflicting pointing requirements for payloads on the same arm. Very fine pointing requirements will necessitate experiments employing image motion compensation techniques. The addition of relative alignment sensors and/or SASP mounted attitude sensors looks promising. SASP will make use of the ability of the PS computer to improve its attitude knowledge by using attitude data from experiments [illegible] y accurate pointing systems.

4.2.5 ACS Approach Considerations

Several SASP ACS options are shown in Figure 4.2.5-1 along with their advantages and disadvantages. Comments relative to the current ACS approach are included.

Actively controlled SASP includes the range of possibilities from distributed actuators and sensors and active isolation and pointing of individual parts of the SASP to relatively simple servoed joints that are currently included ($\pm$180 deg capability). The current approach has been termed "semi-active" because of the arm rotation capability. The inclusion of auxiliary pointing systems to augment SASP pointing capability is a type of multi-sensor, multi-actuator active control from a payload viewpoint.

OPTIONS	ADVANTAGES	DISADVANTAGES	CURRENT APPROACH
ACTIVELY CONTROLLED SASP (STRUCTURAL REFORMATION AND GENERAL POINTING)	• OPTIMAL PAYLOAD MOUNTING BASE • MINIMIZES AUXILIARY POINTING SYSTEM REQUIREMENTS	• COMPLEX HARDWARE AND SOFTWARE • MULTIPLE SENSORS AND ACTUATORS • NO PREVIOUS APPLICATION EXPERIENCE	SEMIACTIVE CONTROL • SASP ARMS MOUNTED ON SERVO CONTROLLED ROTORY JOINTS FOR GENERAL POINTING
RELATIVE ALIGNMENT SENSING	• PROVIDES KNOWLEDGE OF STRUCTURAL MISALIGNMENTS	• REQUIRES SENSORS AND SOFTWARE • POSSIBLE IMPLEMENTATION PROBLEMS	• TBD
AUXILIARY POINTING SYSTEMS	• MUCH DEVELOPMENT WORK COMPLETED • LARGE 2 OR 3 AXIS GIMBAL RANGE CAPABILITY • GOOD ISOLATION PERFORMANCE	• REQUIRES SENSORS, ACTUATORS AND SOFTWARE	• USED FOR PAYLOADS REQUIRING HIGH POINTING PERFORMANCE AND/OR VARIED POINTING DIRECTIONS
PS/SASP USE OF PAYLOAD SENSORS	• IMPROVED ATTITUDE REFERENCE KNOWLEDGE IN VICINITY OF PAYLOAD BEING USED	• REQUIRES DATA PROCESSING	• PS/SASP PROVISIONS TO BE INCORPORATED
INTERNAL INSTRUMENT IMAGE MOTION COMPENSATION	• HIGH IMAGE MOTION STABILITY	• COMPLICATES INSTRUMENT DESIGN	• USED FOR PAYLOADS REQUIRING EXTREMELY GOOD POINTING PERFORMANCE
PS CONTROL OF PASSIVE SASP	• SIMPLIFIES SASP SYSTEMS	• STRUCTURE MISALIGNMENTS NOT DIRECTLY KNOWN	• PS PROVIDES BASIC ATTITUDE REFERENCE AND CONTROL
• SASP, SENSORS	• IMPROVED SASP ATTITUDE REFERENCE KNOWLEDGE	• REQUIRES SENSORS	• TBD

Figure 4.2.5-1 ACS Approach Considerations

Relative alignment sensors can improve attitude reference knowledge at the payload by measuring the structural distortion/misalignment between the payload and attitude reference (currently on the PS). Better attitude reference at the payload is valuable since elimination of experiment pointing system (EPS) for some payloads may be possible and better initial pointing for all payloads is accomplished. The need for relative alignment sensing has not been currently defined.

The use of EPS's is required for payloads which must reorient quickly, view a wide variety of directions, and/or require pointing accuracy/stability greater than that of the PS/SASP structure. Internal instrument image motion compensation will improve pointing performance over that provided by EPS's.

The use of payload attitude sensors will be implemented. This improves the pointing accuracy at the payload by using sensor data from other payloads on the SASP. The pointing accuracy throughout the SASP may be improved significantly over the two degrees uncertainty associated with the Reference PS since the SASP misalignments/distortions are small relative to the two degrees.

The PS control of a completely passive SASP is unrealistic based on the payload requirements and the PS will provide only basic relatively coarse pointing and orientation control.

4.2.6 Disturbances and Momentum Management

Figure 4.2.6-1 defines some of the dynamic disturbances which effect payloads. High frequency disturbances due to rotating machinery such as CMG's and fluid pumps are expected to be small amplitude but may be significant to payloads with very tight pointing stability requirements. Thermal distortions can occur relatively quickly on truss structures when changing from sun to shadow. Platform rotating joint disturbances can be minimized by designing and rotating joint servo to minimize angular accelerations when starting and stopping. Similar designs for the PS solar array drive may be required. The PS CMG's compensate for low frequency disturbances such as gravity gradient and aero-dynamics moments. Payload slewing can cause whole system rotations of 0.1 to 0.2 degree (discussed below). Extreme disturbances such as large PS/Platform maneuvers, orbit keeping operations, or Orbiter docking may require suspension of experiment operations.

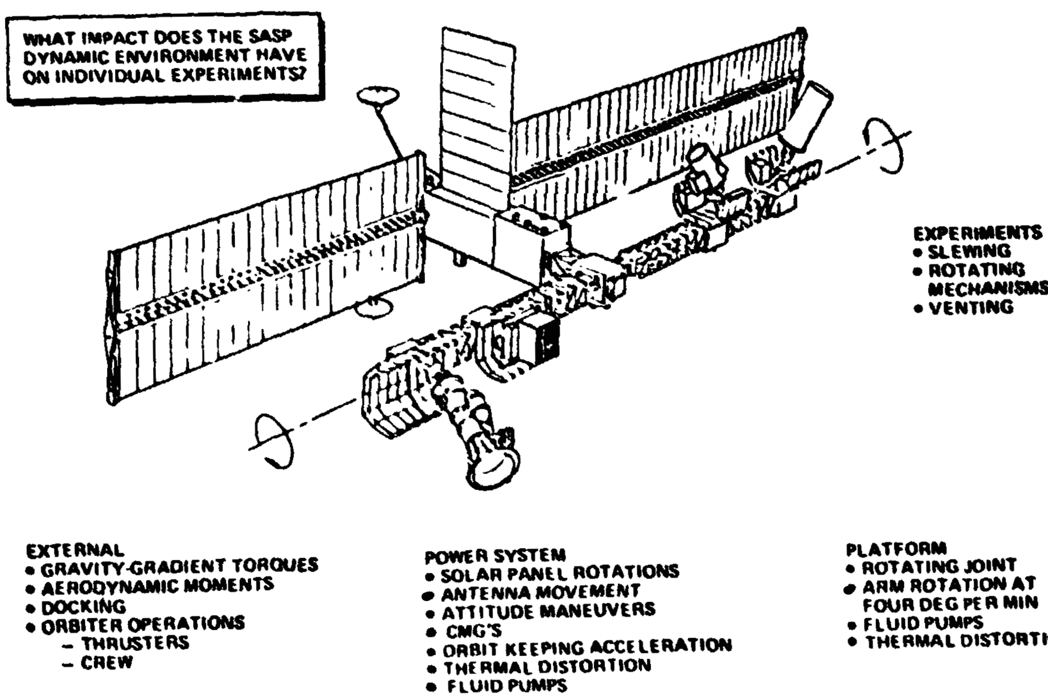


Figure 4.2.6-1 SASP Dynamic Environment

The gravity gradient and aerodynamic moment disturbances for the typical free flyer configuration shown on Figure 4.2.6-2 (with the assumptions defined) were computed to evaluate PS CMG momentum storage requirements for a specific example. The offset configuration was chosen because it provided a principal axes misalignment about the Z-axis. A principal axis misalignment about the Y-axis results from the PS radiator offset. The payloads were assumed to have projected areas corresponding to 1 and 2 Spacelab pallets for the aerodynamic moment computations. The S-175 solar flux parameter represents a high solar activity resulting in a high atmospheric density and large aerodynamic moments. Diurnal bulge affects were included in the atmosphere model which contributes to aerodynamic momentum buildup about all three axes. A time history of moments and moment impulses (momentum) was generated for the X-POP, Y-PSL geometrical axes orientation. The gravity gradient bias resulted in a

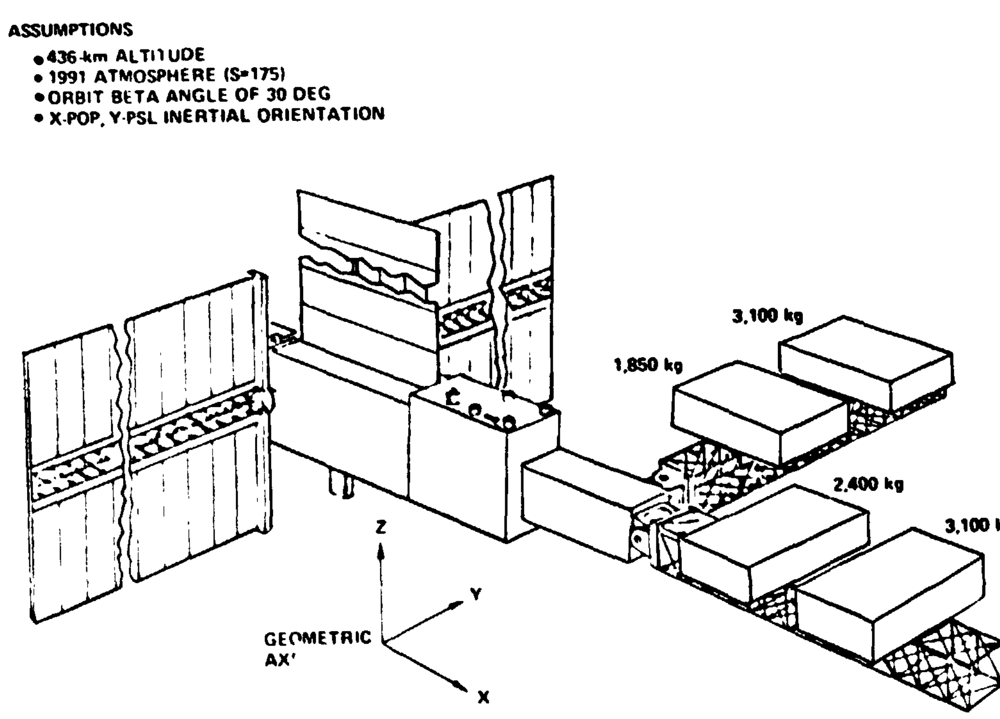


Figure 4.2.6-2 Gravity Gradient and Aerodisturbance Model

momentum buildup of 3590 Newton-meter-sec per orbit. The aerodynamic momentum bias was 796 Newton-meter per orbit, which subtracted somewhat from the gravity gradient bias, and the net momentum bias vector magnitude was 2840 Newton-meter-sec per orbit. The Reference PS has a CMG momentum storage capability of 18,800 Newton-meter-sec peak-to-peak so that a maximum of 6 orbits are possible before a CMG desaturation operation is required if the PS magnetic torquers are not used. The orientation hold duration can be improved to about 9 orbits by using the PS magnetic torquers (900 Newton-meter per orbit). Adding an additional 4 Space Telescope magnetic torquers would increase the X-POP, Y-PSL geometric axis orientation hold time to about 17 orbits or approximately one day.

By reorienting about the Y-axis 2.3 deg and the Z-axis 1.7 deg and sinusoidally reorienting about the X-axis at double orbit frequency with an amplitude of 1 deg every 16 orbits, the approximate X-POP, Y-PSL orientation can be held indefinitely. If the magnetic torquers are used, the reorientation angles can be reduced and the X-axis maneuver eliminated (for sufficiently large orbit inclinations). The X-axis maneuver is required by the aerodynamic torques (small in this example) and cannot be offset by gravity gradient torques since no gravity gradient bias torque is available perpendicular to the orbit plane (vehicle X-axis).

Figure 4.2.6-3 shows the A-10 payload configuration and the associated mass properties and principal axes misalignments (Z-Y-X-axes Euler rotation, body to principal axes). The largest misalignment is about the Z-axis with relatively small misalignments about the X- and Y-axes. For the Z-LV, Y-POP orientation, the gravity gradient disturbance torques can be eliminated by skewing the orientation about the X- and Y-axes about 1.2 and 0.9 degrees,

respectively. No skewing about the Z-axis is required since it is local vertical. Skewing about the Y-axis is all that is required to eliminate the bias gravity gradient momentum bias buildup. Even though the Y-principal axis misalignment is small, the PS CMG's must be desaturated after only four orbits (eight orbits if the peak-to-peak CMG capability is assumed). The Y-axis momentum buildup with no orientation skewing is about Newton-meter-sec per orbit perpendicular to the orbit plane. This is more than is possible to remove with eight Space Telescope magnetic torquers, particularly at low orbit inclinations where the available magnetic moment is low, perpendicular to the orbit plane. Therefore, at least Y-axis skewing would be desirable.

Mass 42300 KG

CG X 7.28 M

Y 1.78 M

Z 0.46 M

Principal Moment of Inertials

X 9.2×10^6 KG-M^2

Y 4.5×10^6 KG-M^2

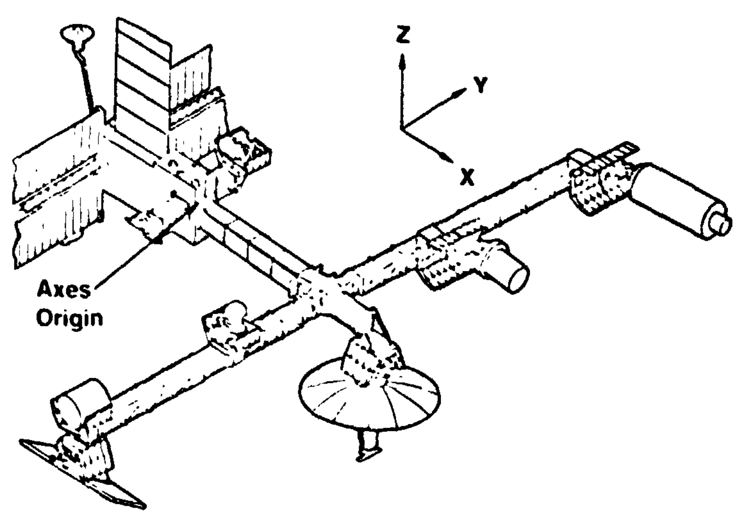
Z 13×10^6 KG-M^2

Principal Axes Misalignment

ΦZ -15 Deg

ΦY 0.6 Deg

ΦX -1.4 Deg



Z-LV,Y-POP Orientation

- No Skewing Required About Z-Axis
- Skew ≅ 1.2 Deg About X-Axis for No Inertially Cyclic Gravity Gradient Torques
- Skew ≅ 0.9 Deg About Y-Axis for No Bias Gravity Gradient Torque
- No Skewing Requires PS CMG Desaturation Every 4 Orbits (Excluding Aero)

Figure 4.2.6-3 A-10 Control Considerations

The feasibility of skewed orientations or orientations requiring periodic CMG desaturation operations depends on multiple payload accommodation requirements which are not available at this writing.

Typical maneuver disturbances result from vehicle reorientation, pointing system payload reorientation, and pointing system raster scanning. The torque histories used to effect these maneuvers can be designed to minimize the structural responses. Torque histories with "sharp corners" excite higher frequency vibrations. Smoother torque histories can reduce response at higher frequencies. For example, this can be done by implementing a raster scan as a spiral motion rather than a square or rectangular motion.

Lower frequency responses can be minimized by designing raster scan or maneuver periods to be long relative to flexible structure periods of vibration. This may not be too constraining since structural vibration periods are expected to be less than 10 sec (0.1 Hz) except for the solar array. Smaller torque magnitudes are consistant with longer maneuver periods and this reduces the disturbance effects.

Optimal maneuver torque histories can be defined which effectively limit energy input to the structure near given frequencies and thus desired structural modes can be restrained from being excited. The more complex the torquing history the more modes that can be accommodated with minimal response. This concept applies directly to reorientation maneuvers, but does not appear to be as applicable to a rastering situation where a basic raster trajectory periodicity may be desirable.

Figure 4.2.6-4 depicts torque histories which result in a rigid body reorientation (i.e., at the end of the maneuver, the rate and acceleration are zero but

the attitude has changed). The square wave approach is a minimum time approach for a given torque magnitude, but the quick change in acceleration (high jerk) can excite vibrations with frequencies above the square-wave fundamental frequency. The $(1-\cos \omega t)/2$ function smooths the corners to reduce the high frequency excitation, but the fundamental frequency is relatively unchanged. The torque optimized to the structure shows an approach which sums cosines at various frequencies which result in minimum energy input to harmonic oscillations at desired frequencies. The starting and stopping jerk of this example would excite high frequency oscillations however. Further work on shaped torque techniques is required.

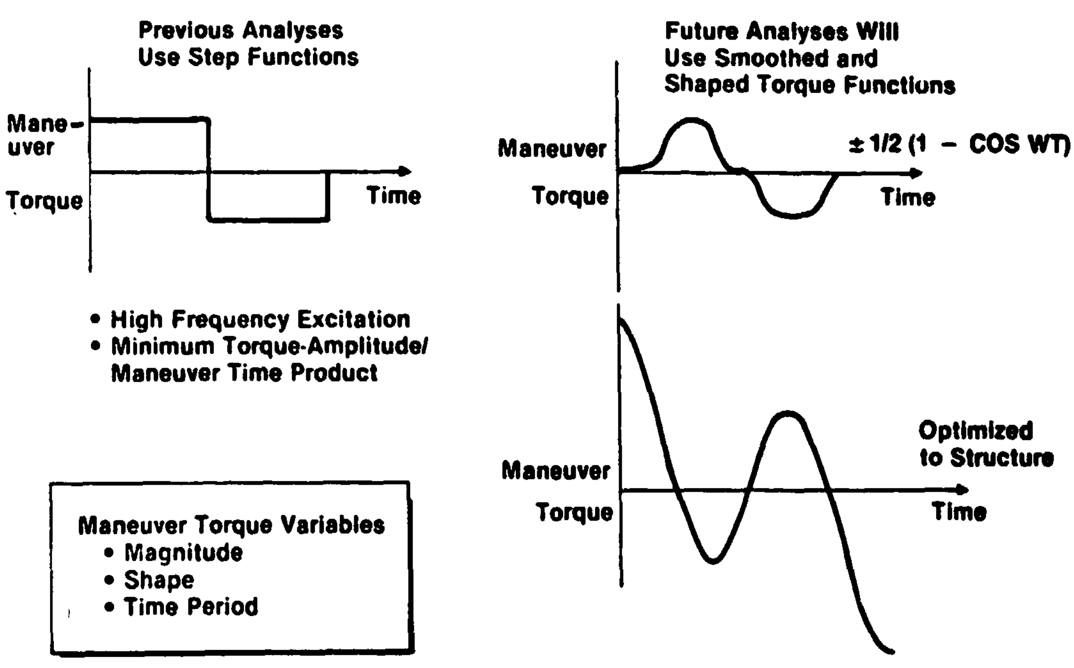


Figure 4.2.6-4 Maneuver Torque Time Histories

4.2.7 SASP Momentum Dump Options

Several approaches to PS CMG momentum dumping are shown in Figure 4.2.7-1. All are possible with the Reference PS capability with the exception of a possible requirement for additional magnetic torquers. The additional magnetic torquers could be mounted on the PS or SASP. The requirement for magnetic torquers could be mounted on the PS or SASP. The requirement for magnetic torquing capability and momentum storage capability will ultimately depend on the orientations flown and the sensitivity of the payloads to variations about the basic orientations. Long orientation-hold durations with no variation from the orientation leads to large momentum sto age requirements and/or large magnetic torquing capability requirements. Detail orientation requirements are needed to define CMG momentum storage requirements and momentum dump procedures.

Option	Comment
• Reference PS Magnetic Torquing System	• Can Operate Continuously but Only Limited Capability (~900 N-M-S per Orbit) • Magnetic Field Contamination Must Be Considered
• Addition of a SASP Magnetic Torquing System for Added PS/SASP Capability	• Detailed Orientation Requirements Needed to Identify Requirement
• Orientation Selection to Minimize Momentum Buildup	• Includes Limiting Available Orientations and Using Skewed Orientations • May Impact Payload Viewing
• Periodic Maneuvers to Advantageous Orientations	• Maneuver May Disrupt Payload Operations • Frequency Depends on Orientation and Configuration
• Continuous Maneuvering	• May Impact Payload Operations • Maneuvers Normally Small
• Momentum Feedback for Onboard Orientation Commanding	• Can Operate Indefinitely • Results in Skewed and/or Continuously Maneuvering Orientations

Figure 4.2.7-1 PS CMG Momentum Dump Options
(Selection is Dependent on Orientation and Payload Sensitivity)

4.2.8 Dynamics Analysis

Early dynamics analysis effort consisted of generating a simplified bending model of the PS/SASP crossarm configuration. Later in the study a higher fidelity NASTRAN dynamic model was generated. A rigid body model of the AGS (Annular Suspension Pointing System Gimbal System) was used to define the payload line-of-sight motion to linear-acceleration-at-the-gimbal transfer function. This transfer function was used to estimate LOS (line-of-sight) disturbance for the AGS mounted on a flexible SASP and disturbed by another AGS performing a slew maneuver.

Figure 4.2.8-1 was used to choose a controller bandwidth. Figure 4.2.8-2 applies to inertial hold orientations and rotations about the axis perpendicular to the orbit plane (the 1 axis). The solid curves define maximum vehicle attitude error due to gravity gradient disturbances versus PS attitude control system bandwidth (attitude feedback) for several different vehicle moment of inertia configuration factors (k). Typical disturbance frequencies are noted along with a realistic control system bandwidth region. The rule of thumb control system design criteria of disturbance frequencies, controller bandwidth and structural frequencies all being separated by factors of ten are applicable except for the relatively low solar array flexible frequencies derived from previous studies (PEP, 25 kW, PS, OSM). The moment of inertia of the solar array is not small compared to the whole vehicle and a 0.01 Hz controller bandwidth may result in low damping at the solar array frequency. The dynamic model bending frequency range (based on the NASTRAN model) is noted and is a factor of 10 above the 0.1 Hz maximum controller bandwidth.

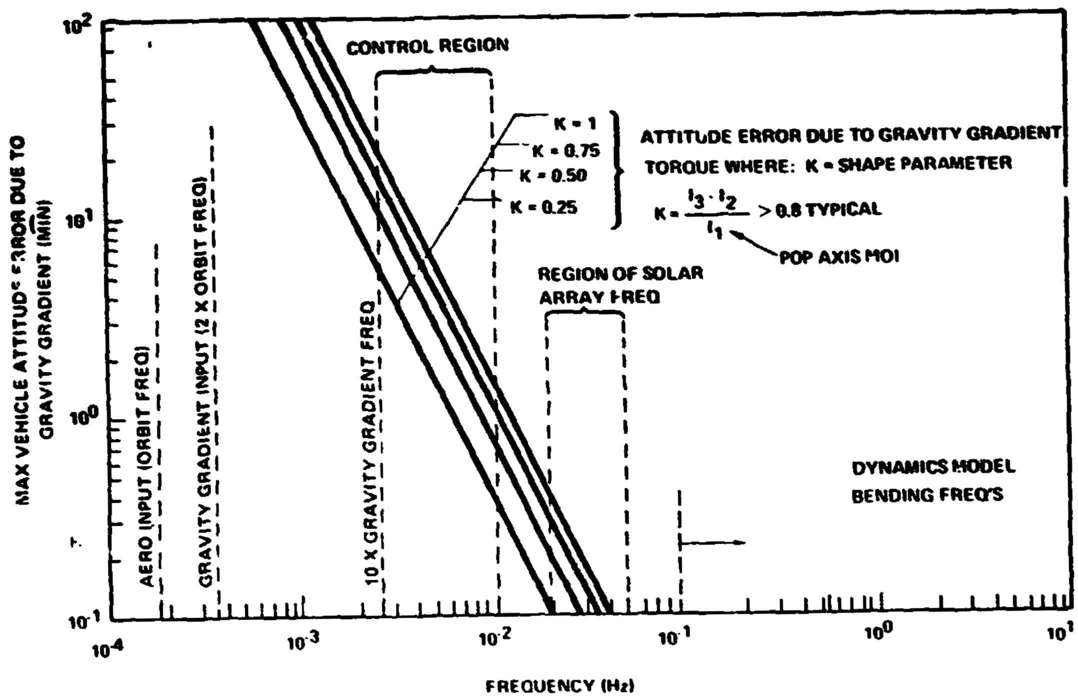


Figure 4.2.8-1 ACS Frequency Considerations, Inertial Hold, POP Axis

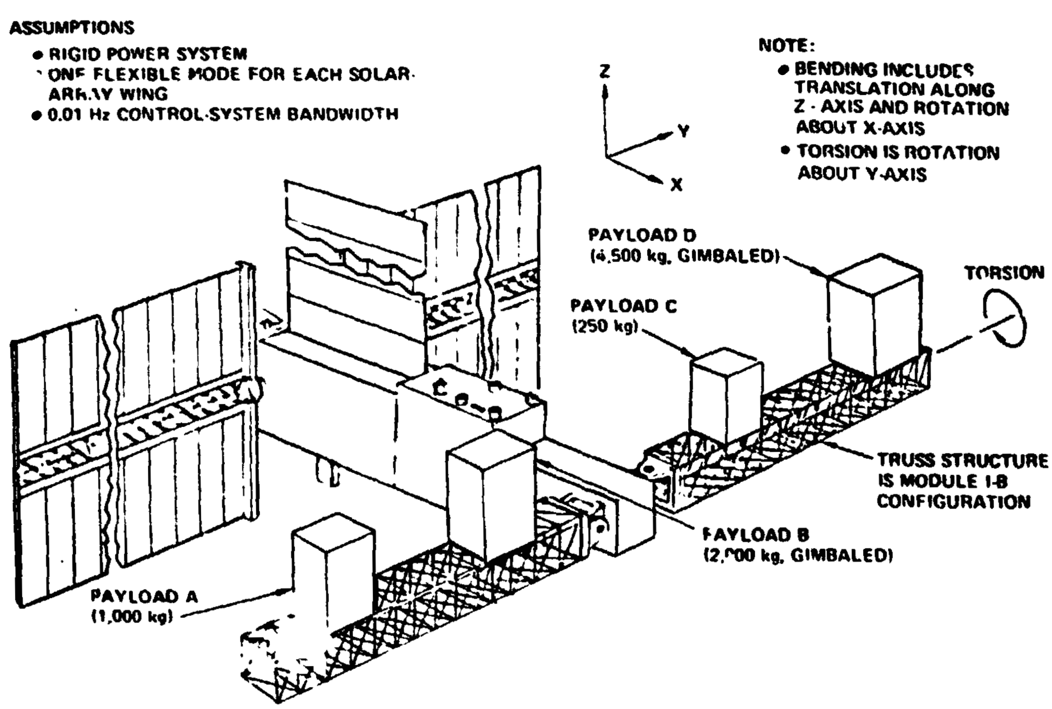


Figure 4.2.8-2 SASP Simplified Dynamics Analysis Model

For example, the maximum gravity-gradient-induced attitude error for a worse case configuration (K=1) is 1.4 arc min for a controller bandwidth of 0.01 Hz. This corresponds to platform pointing stability and could be improved (a factor of two or more) by using integral or attitude feedback in the PS attitude control subsystem (ACS).

A simplified flexible dynamics model of the platform configuration shown in Figure 4.2.8-2 was used for computer analysis of bending and torsion modal frequencies and mode shapes. The platform truss structure was modeled as a beam (module configuration I-B) and the PS was considered rigid. Each solar array wing was considered a cantilevered massless beam with a point mass attached at the outer end. A solar array cantilever (from the PS) frequency of 0.02 Hz was assumed. The PS was connected to inertial space with a rotational spring representing the control system with a 0.01 Hz bandwidth. The gimballed payloads were assumed to have no rotational inertia (except for simulated pallets) which represents the isolation capability of the auxiliary pointing system. The simplified banding model had a total of 32 degrees-of freedom; the torsion model 6 degrees-of-freedom. The length of the standoff structure between the PS and the crossarms was increased subsequent to generation of the simplified model which lowered frequencies somewhat. The NASTRAN model (discussed elsewhere) modeled the longer offset structure.

Figure 2.7.2-3 contains the results of the computer analysis of the simplified SASP dynamic model. These are discussed in Section 2.7. Figure 2.7.3-2 depicts the mechanics of auxiliary pointing system (APS) line-of-sight (LOS) disturbance. The disturbance input is linear acceleration of the gimbal perpendicular to the LOS. Other motions cause only second-order disturbance

effects (such as gimbal friction) at lower frequencies. Pointing system and payload flexibility can become significant at higher frequencies but were not modeled here. The gimbal acceleration ($A_{\perp LOS}$) is measured by a base-mounted accelerometer and the signal to the gimbal torquer to cancel the mechanically induced disturbance torque. Accelerometer measurement error (due to accelerometer bandwidth, scal factor, bias, resolution, sample frequency and mounting location) and similar gimbal torquer errors as well as mass properties prediction errors (i.e., error in estimating $K_T D$), result in less than 100 percent of the mechanical disturbance being cancelled by the accelerometer feedforward s gnal. Therefore, the disturbance to the LOS due to an acceleration disturbance is not zero, though it is small for certain frequencies.

Acceleration disturbances perpendicular to the LOS result from rigid body motion and from flexible dynamic motions. The figures on the right of Figure 2.7.3-2 show how SASP bending and torsion motions generate acceleration and LOS disturbance inputs to the APS.

The model shown on Figure 4.2.8-3 was used to estimate the isolation capability of an auxiliary pointing system. The accelerometer was assumed to have a 20 Hz bandwidth, damped at 40 percent of critical. The payload assumed was the SIRTF. The controller gains assumed were:

K_1 = 1 (non-dimensional)

$K_R = 16\ sec^{-1}$ 1 Hz bandwidth

$K_P = 64\ sec^{-2}$

and were supplied by Sperry as typical for the Annular Suspension Pointing System Gimbal System (AGS). J_{EQ} and J_{EQ} are the gimballed moment-of-inertia value and estimate, respectively. And similarly for K_{TD} and K_{TD}, the

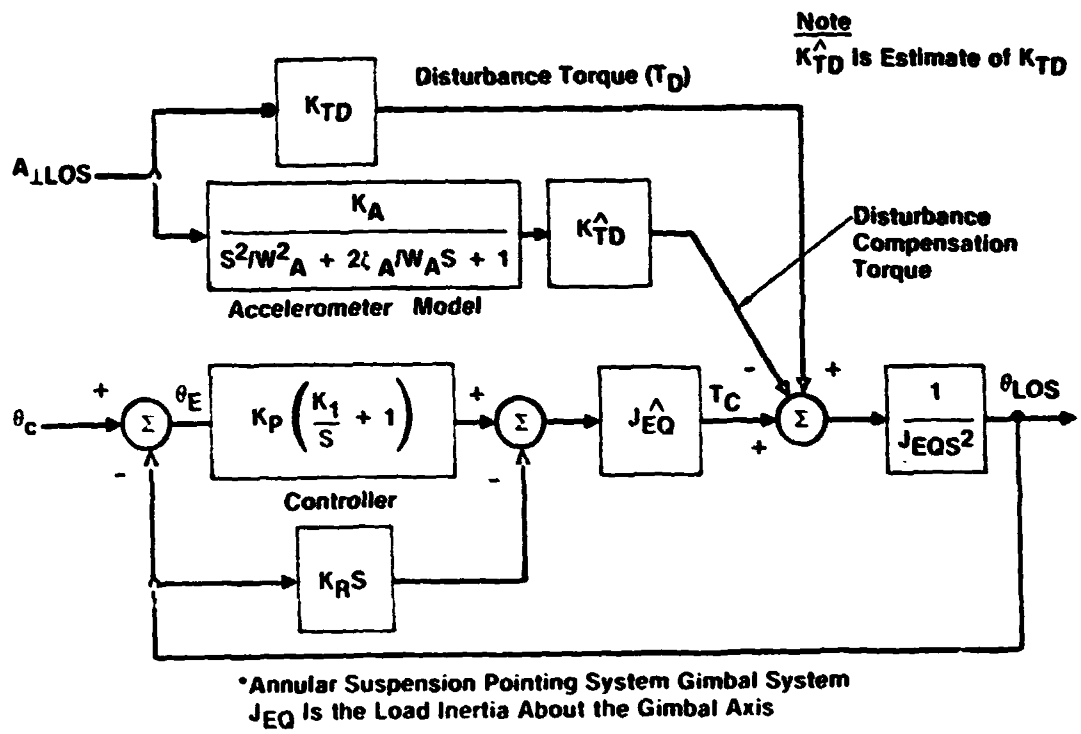


Figure 4.2.8-3 AGS* Disturbance and Controller Model

gimballed mass moment (see Figure 4.2.8-2). K_{TD} error values of 0, 1, 5, and 10 percent were analyzed. The SIRTF/AGS mass properties assumed were:

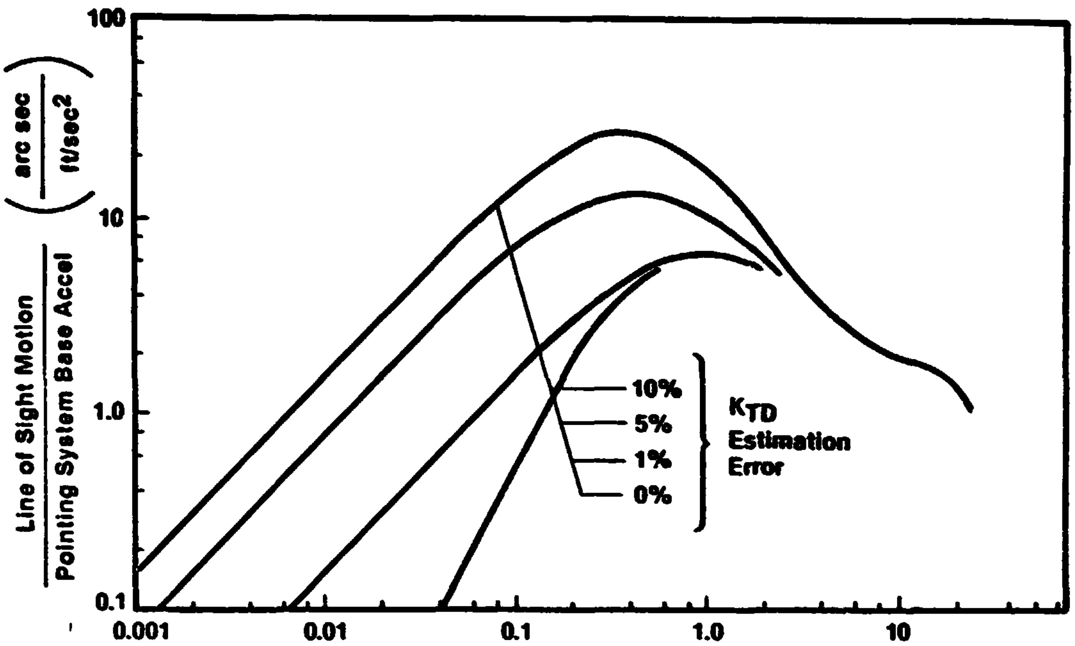
m = 3310 KG

l = 3.64 m

K_{TD} = 12,000 KG-m

J_{EQ} = 48,000 KG-m^2

The line-of-sight (LOS) disturbance per gimbal acceleration performance is shown in Figure 4.2.8-4. The transfer function peaks near the 1 Hz gimbal servo bandwidth and again at the 20 Hz accelerometer bandwidth. Structural dynamic resonances in the SIRTF and AGS add sharply defined peaks to these frequency responses but are eliminated for this simplified analysis. Assuming a five percent K_{TD} error, a peak value of 420 arc-sec line-of-sight (LOS) error occurs per g of acceleration at 0.4 Hz. As shown below, this



*Annular Suspension Pointing System Gimbal System

Figure 4.2.8-4 AGS* Gimbal System Acceleration Disturbance Isolation Capability SIRTF Payload

isloation capability is quite good for the acceleration disturbance levels expected. The results and an interpretation of their impact are contained in Figure 2.7.3-3 in Section 2.7.

4.2.9 Thermal/Structure Response

In Figure 2.7.4-1 of Section 2.7, the structural response to thermal gradients were presented. The mechanical dynamics were modeled as a resonance representing the first bending mode. Higher frequency modes will be excited by the thermal transient but first mode should dominate since .he thermal deformation "shape" is similar to the mode shape of the first bending mode. The simplified dynamic model described above was used to define the first mode bending frequency (0.55 Hz).

The thermal transient at the orbit day-night transition was modeled as a linear system operating about the midpoint temperature of the transient. This temperature transient was input as a force through a gain factor to the resonance and the resulting acceleration peak was determined. The gain factor is the ratio of static thermal deformation per degree of temperature differential (ΔT) times the effective spring constant of the first bending mode. The transition from day to night takes about 7.8 sec which is short compared to the thermal time constant (1200 sec) but long compared to the first bending mode period (1.8 sec). Therefore, the input power was modeled as a step and a ramp for 7.8 sec to see the effect on the resulting acceleration (the ramp reduces acceleration by a factor of 6).

The results of the analysis indicate accelerations at the outer end of a SASP of well under 10^{-6} g's at the 0.55 Hz first mode bending frequency. Based on the previously described AGS pointing system model, the resulting payload line-of-sight disturbances are below the 0.01 arc-sec noise level of the Annular Suspension Pointing System. Therefore, it is preliminarily concluded that thermal deformation transients for graphite/epoxy structure are not significant to either low-G payloads or pointing payloads. For aluminum structure, the thermally induced accelerations are on the order of 10^{-4} g's which exceeds the Materials Processing payload 10^{-5} G requirements. Note, however, that the accelerations calculated apply to the outer ends of the SASP crossarms and a materials processing payload normally would be mounted closer to the c.g. (because of orbital dynamics and centrifugal acceleration considerations) where thermal deformations may be much less. The 10^{-4} G acceleration at 0.55 Hz is not a small input to an APS. Aluminum structure may cause LOS errors of about 0.04 arc sec which may not be acceptable to all payloads.

Note that the NASTRAN dynamics model showed lower frequencies which would tend to reduce the thermally induced accelerations shown above.

4.3 COMMUNICATIONS AND DATA MANAGEMENT TRADES

The key trade studies that were performed in the Communications and Data Management area are defined in Figure 4.3-1. This figure also shows the factors considered in each trade study. The three trade studies were: (1) centralized versus distributed payload control (data processing support); (2) payload data storage allocation to Power System, Platform, or pallet; and (3) experiment data multiplexing allocation to Power System versus Platform.

Centralized vs Distributed Payload Control

- On-Orbit Integration
- Prelaunch Checkout Autonomy
- Payload Data Autonomy
- Overall Data Processing Efficiency

Payload Data Storage on Power System, Platform, or Pallet

- Accommodation of First Order Platform Payloads
- Efficient Use of High-Rate TDRSS Channels
- Cost Deferral
- Minimize High Rate Data Handling

Multiplexing on Power System vs. Platform

- Accommodation of First Order Platform
- Cost Deferral
- Compatibility with Data Storage Configuration

Figure 4.3-1 Data Management Options and Selections

4.3.1 Centralized Versus Distributed Payload Control

4.3.1.1 Overall Requirements Summary

The SASP Data Management System provides a data interface with the payloads. Commands going to the payloads and engineering and scientific data coming from the payload cross this interface. Processing associated with this data can be allocated to the payload, the host vehicle (Power System/SASP), or

the ground. For the large variety of payload configurations planned for SASP, it is probable that some data processing will be required at each of the above locations. It is desirable to develop processing allocation guidelines that can be used to develop a SASP data management system configuration.

4.3.1.2 Important Factors and Considerations

Some of the important factors in this study are shown in Figure 4.3-1. One factor that is unique to the SASP concept is that the payload and the host vehicle (SASP) data system will be integrated on orbit after a payload exchange. Previous experience indicates that this process can be extremely time-consuming, especially if there is a complex interface between the payload and the software in the host vehicle. Another important consideration is the des, to provide a payload interface that emulates a Spacelab payload interface to the extent that Spacelab payloads can be flown on SASP with minimum change. Where the Spacelab payload relies on the Spacelab experiment computer for data processing support, this desire is not consistent with the goal of optimizing the on-orbit integration of the interface.

4.3.1.3 Work Accomplished

The data interface defined for Spacelab payloads for Missions 1, 2, and 3 was reviewed. Most of these payloads rely on the experiment computer for some level of support. However, it was determined that 50% to 60% of these payloads have a Dedicated Experiment Processor on the payload side of the interface. The trend on Spacelab payloads, and the desire of the principal investigators, is clearly in the direction of dedicated processors on the payloads. One of the primary drivers of this trend is the autonomy in development and integration that is provided.

The processing functions associated with payload operations (for Spacelab payloads) were investigated. Typical functions are listed in Figure 4.3.1-1. This figure also suggests an allocation of these processing functions to a central processor (SASP or Power System) and a dedicated experiment processor.

Central Processor

- **Manage common resources (eg power)**
- **Down load experiment programs**
- **Relay commands from ground**
- **Provide common platform data (e.g. attitude, position)**
- **Macroschedule experiment operations**

Dedicated Experiment Processor

- **Equipment checkout and calibration**
- **Experiment operation (microscheduling)**
- **Input data/command processing**
- **Data acquisition (formatting, annotation)**
- **Data processing (sorting, correlating, estimating)**

Figure 4.3.1-1 Experiment Onboard Processing Function Allocation Example

4.3.1.4 Conclusions and Comments

To provide a SASP design that will allow on-orbit integration of payloads, payload data processing should be allocated to a dedicated experiment processor except for functions that involve direct Power System interfaces (ground communication, power management, etc.). Central processor support to payloads should be limited to top-level payload control, central resource management, communication interface support, and similar functions that cannot be done at the payload. This approach implies some possible impact to Spacelab payloads. Further study is required to establish the degree of impact and the alternatives available to relieving that impact.

4.3.2 Payload Data Storage on Power System, Platform, or Pallet

4.3.2.1 Overall Requirements Summary

Payload data storage is required on-board the Platform (1) to prevent data loss during periods of TDRSS non-availability, and (2) to accumulate data so that it can be dumped to TDRSS at high rates, thereby making better use of TDRSS resources. This payload data storage could be handled on the Power System, the Platform, or the payload carrier (pallet). The ability to communicate with TDRSS at any given time may be limited by visibility (orclusion by the earth), Power System antenna look angles, or higher-priority users.

4.3.2.2 Important Factors and Considerations

Several factors enter into this trade. First, it is desirable to minimize high rate data handling to reduce data equipment complexity. If data storage were provided on the pallets, high rate dumps of multiple-pallet data would require that the outputs of multiple high rate recorders be multiplexed. A better approach would seem to be to acquire multiplex and store the data then dump the already multiplexed data at a high rate.

A second factor is the goal of providing data storage for payloads on the First Order Platform. Since Spacelab payloads have available the 32 Mbps Spacelab data recorder, it seems reasonable to provide at least the equivalent capability for the First Order Platform.

A third factor is the desire to defer the deployment of storage capability (beyond that required by First Order Platform payloads) until the Second Order Platform is placed in operation. This has the advantages of (1) deferring costs, and (2) allowing the use of later technology for the Second Order Platform data storage capability.

4.3.2.3 Work Accomplished

Alternative data storage technologies were investigated to identify candidate technologies for a mid-1980's platform. Figure 4.3.2-1 compares several data recording technologies and identifies near-future limits in magnetic storage devices. Current (Spacelab) recorder technology provides 3.8×10^{10} bits total storage on a single tape recorder with maximum record and playback rates of 32 Mbps. Development work planned or currently in progress will lead to recorders with record/playback rates in excess of 100 Mbps and total storage capabilities of up to 10^{12} bits. Other technologies (e.g., bubble memories) have promise but are not expected to be developed to the extent that they can meet SASP requirements by the 1985 time period.

RECORDING TECHNIQUE SELECTION

TYPE	FEATURES	LIMITATIONS
MAGNETIC	• IMMEDIATE READOUT ERASABLE, RERECORDABLE	BANDWIDTH LIMITED
ELECTRON	LARGE CAPACITY LARGE BANDWIDTH	DELAYED READOUT REQUIRES FILM PROCESSING
HOLOGRAPHY	LARGE CAPACITY LARGE BANDWIDTH REDUCED SIZE AND POWER	DELAYED READOUT REQUIRES FILM PROCESSING

MAGNETIC RECORDING LIMITS - NEAR FUTURE

TYPE	BITS/IN	TAPE SPEED (IN/SEC)	CHANNELS	BIT RATE (BPS)
LONGITUDINAL	50 K	120	2	12 M
ROTARY HEAD	50 K	1,000	2	100 M

AVAILABLE OFF THE SHELF – 1978

INPUT DATA RATE (BPS)	STORAGE TIME (MIN)	TOTAL STORAGE (BITS)
32 M	20	3.84 X 10 E 10

Figure 4.3.2-1 Recorder Limitations

4.3.2.4 Conclusions and Comments

The SASP should provide data storage for the payloads. A centralized payload data storage facility will be more cost effective than payload-provided storage, and will simplify the overall payload data management problem. Some payload data storage, at least equivalent to that provided by Spacelab, should be provided by the Power System. This capability should be supplemented by additional tape recorders in the Second Order Platform support module to handle the increased data quantities expected from Second Order Platform payload groups and to provide higher data dump rates for the later time period when TDRSS loading will be higher.

4.3.2.5 Multiplexing on Power System or Platform

Multiplexing of payload data (and Platform/Power System data) is required to make use of the available communication channels. For a second order platform configuration, the multiplexing function can be concentrated in the Power System or it can be distributed between the Power System and the Platform Support Module. For the same reasons that were cited in the data storage trade, and to provide compatibility with the selected data storage configuration, the multiplexing function should be provided in the Power System to meet First Order Platform requirements. This should be supplemented with additional multiplexing capability in the Second Order Platform. This approach, as in the data storage approach, allows costs to be deferred where possible, and allows the possibility of later technology being used for second order platform data system elements.

4.4 BERTHING EQUIPMENT AND ALTERNATE PAYLOAD CARRIERS

This paragraph reports on trades performed to resolve key issues in the configuration design.

4.4.1 SASP/Orbiter Structural Interface System

Several Orbiter berthing subsystem options were compared for platform initial deployment and on-orbit servicing.

4.4.1.1 Requirement Summary

Table 4.4.1-1 presents the requirements for the berthing subsystem.

- PROVIDE A BERTHING INTERFACE AND A STRUCTURAL BRIDGE BETWEEN THE ORBITER AND FREE-FLYING SPACE PLATFORM OR A POWER MODULE.
- SYSTEM SHALL INTERFACE WITH ORBITER IN THE FORWARD PORTION OF THE CARGO BAY AND BE COMPATIBLE WITH THE INSTALLATION OF SPACELAB MODULE, SHORT ACCESS TUNNEL, AIRLOCK, MMU INSTALLATIONS, KU ANTENNA, AND LEFT AND/OR RIGHT HAND RMS INSTALLATION.
- THE CENTERLINE OF THE DEPLOYED INTERFACE SHALL BE LOCATED AT Yo = 0, Zo = 515 MINIMUM, AND +Xo = 633 MAXIMUM.
- THE BERTHING SYSTEM SHALL STRUCTURALLY ATTACH TO THE ORBITER THROUGH THE USE OF STANDARD ORBITER KEEL AND LONGERON BRIDGE FITTINGS AND JOURNALS.
- THE STRUCTURAL STIFFNESS OF THE BERTHING SYSTEM SHALL BE A 4×10^6 FT/LB PER RADIAN IN BOTH BENDING AND TORSION. IN THE DEPLOYED POSITION THE SYSTEM SHALL EXHIBIT NO LOOSENESS OR BACKLASH IN JOINTS OR DRIVE ACTUATORS.
- SYSTEM SHALL NOT PRECLUDE EVA EGRESS FROM ORBITER AIRLOCK.
- SYSTEM TO PROVIDE CAPTURE LATCHING, SECURING OF INTERFACE PLUS UMBILICAL ENGAGEMENT.
- THE BERTHING SYSTEM TO TRANSFER ELECTRICAL POWER, AND DATA AS REQUIRED.
- THE ACTIVE PORTION OF THE MECHANISM TO BE ON THE ORBITER SIDE OF THE INTERFACE.
- INTERFACE WITH POWER SYSTEM AND/OR SASP IN A MANNER TO PLACE $\pm$Y AXIS PAYLOADS AT ORBITER STA Xo 550 MAXIMUM.
- PROVIDE +90° ROTATIONAL CAPABILITY AT SASP/ORBITER INTERFACE (OPTIONAL REQUIREMENT)

Table 4.4.1-1 SASP/Orbiter Berthing System Requirements

4.4.1.2 Important Factors and Considerations

The selected berthing concept should have minimum impact on the current Orbiter and Power Systems designs and operations. Additionally, the design should not unduely complicate the platform design. Compliance with these considerations will be reflected in a lower cost and weight with enhanced safety and reliability.

An important aspect of the platform design is the ability to accept a wide variety of payload sizes and geometries. Achieving this goal of flexibility is an important consideration in the berthing subsystem design.

4.4.1.3 Work Accomplished

During the study, various berthing system options were investigated as shown in Figure 4.4.1-1. The initial berthing provision shown in Option 1 is a deployable adapter that places the Platform outboard of the cargo bay and also forward along the (X) axis. Rotational provisions permit full utilization of the RMS. However, this concept is not compatible with the Spacelab sortie mode. Option 2 is the MSFC baseline concept which is a truss-type structure which mounts to the Orbiter sill and keel fittings. The adapter remains in the cargo bay and is delivered each time a berthing operation is desired. The upper section is deployable and incorporates four RMS end effectors at the interface. Option 2 deploys from the cargo bay at approximately Sta Xo 633 thereby placing the Platform in a manner that restricts RMS operations. Option 3 adds an extension to the interface and moves the berthing port forward to provide clearance between (-Y) axis payloads and the RMS. Rotational capabilities are included to permit rotating the Platform to clear the cargo bay and/or place payloads within the RMS reach envelope. Options 1, 2, and 3 are concepts that remain with the Orbiter and require cargo bay volume and

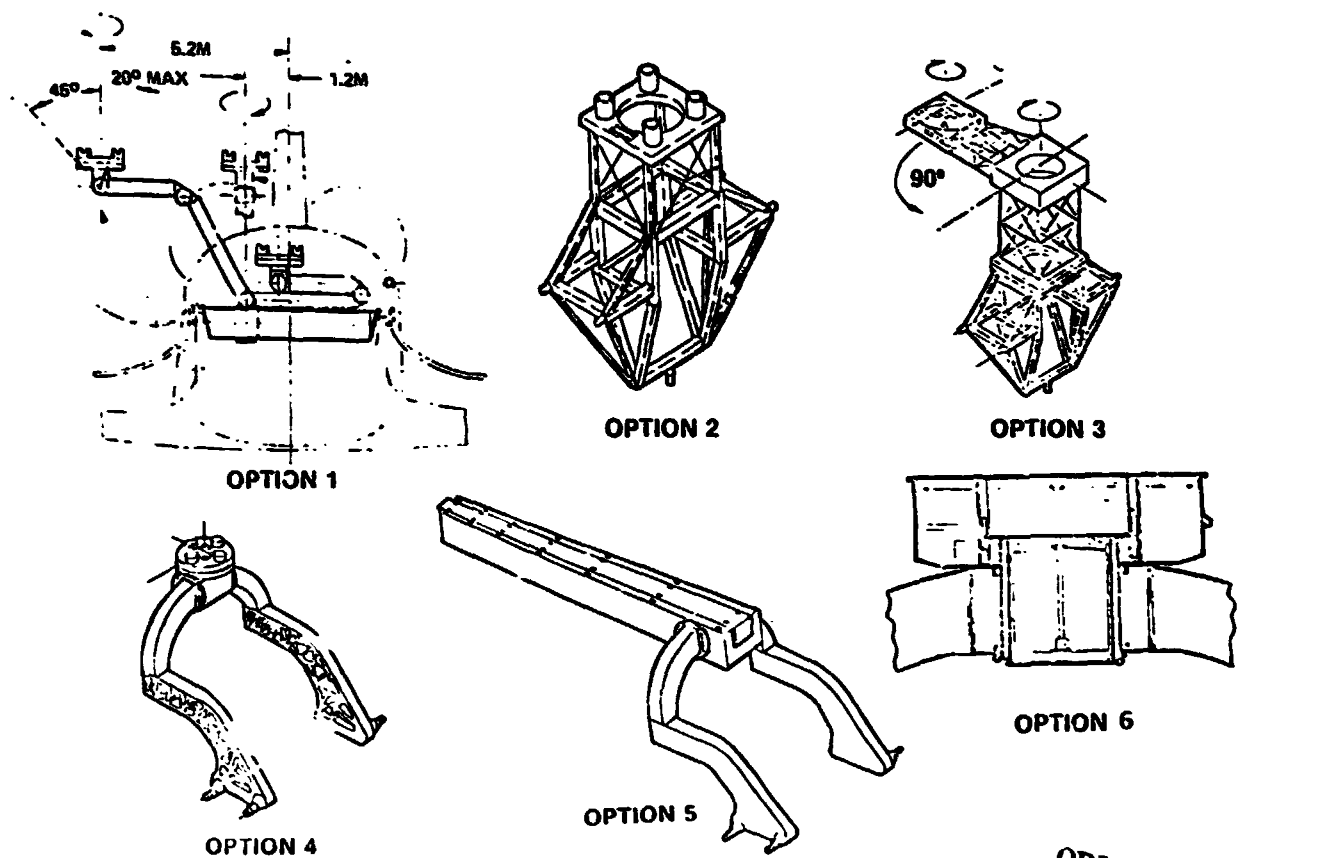
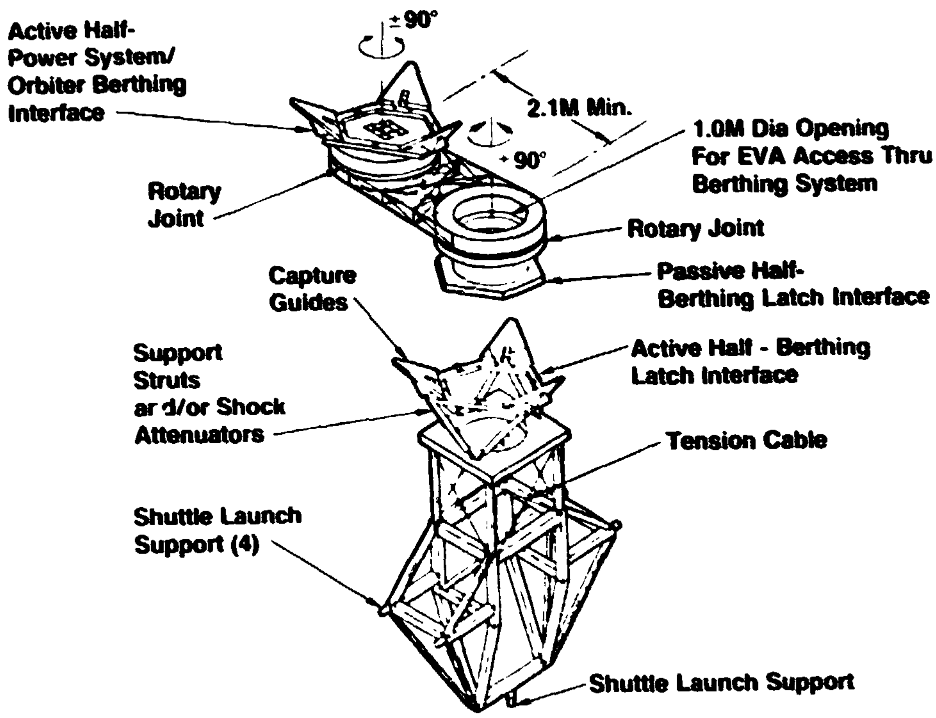


Figure 4.4.1-1 Orbiter Berthing Interface Options

weight allocations. Options 4 and 5 are configured to remain with the platforms. If the Platform is large with payload ports out of reach of the RMS, the first four options require reberthing the Orbiter to service the remote ports. Option 5 eliminates the requirement for reberthing by permitting the Orbiter to be moved along a platform arm. Option 6 adds a turret to the provisions for linear translation so that the Orbiter can be moved down one arm and then along an intersecting arm as required to reach all platform ports.

4.4.1.3.1 First Order Platform Berthing System - The First Order Platform Berthing System shown in Figure 4.4.1-2, incorporates an Orbiter Berthing System and a 1st Order Platform Berthing Adapter. The Orbiter System shown is the concept defined in MSFC's 25 kW Power System Reference Document #PM-001, dated September 1979. The structure is attached to Orbiter fittings at



Orbiter Berthing System Extended

Figure 4.4.1-2 1st Order Platform Berthing System

Sta Xo = 617 and Xo 675.6. The system deploys approximately 4 ft in the +Zo direction for clearance between the berthed spacecraft and the Orbiter. The Orbiter Berthing System is configured to be compatible with a Spacelab installation. The structural interface shown is the current active berthing latch concept being studied by MDAC under the Space Platform Advanced Technology Study, Contract NAS9-16001 and described in paragraph 3 3 4. The mechanism provides the power to capture, latch, and secure the passive half of the interface. Power to deploy the umbilicals, etc., is provided by the active side of the interface. The 1st Order Platform Berthing Adapter is approximately 2.1m long and incorporates an active and a passive interface system. The passive interface is configured to mate with the Orbiter Docking/Berthing System shown. The active berthing mechanism is identical to

the Orbiter system with the support struts and/or shock attenuators removed. Since the Power System will be passive during the berthing operations, captive latching and umbilical engagement will be performed by the adapter with power from the Orbiter. Rotational capabilities of $\pm 90°$ are provided at both interfaces adding flexibility in placing 1st order platforms in a position to minimize c rgo bay obstruction and maximize RMS reach capability.

4.4.1.3.2 2nd Order Platform Berthing System - The 2nd Order Berthing System shown in Figure 4.4.1-3 resulted from the requirement of servicing the SASP with the Orbiter limited to a single rendezvous/berth with SASP. The concept incorporates a telescoping boom and the Orbiter Berthing System. The telescoping boom is an integral part of the 2nd Order SASP support module and is stowed under the support module structural extension during launch. The passive half of the interface is configured to mate with the Orbiter Berthing System. Power to mate the interface is supplied by the Orbiter. The Orbiter Berthing System shown is the standard system described in paragraph 5.3. The 7.6 m retracted length of the boom enables the Orbiter to be rotated to place inner (Y) axis payloads within reach capabilities of the RMS. The 14.6 m deployed length together with the rotational features, enables the Orbiter RMS to service all SASP payload locations and completely service the Power System, including replacement of the Reboost Module. A detailed description of the Telescoping Boom is in Section 5, Paragraph 5.3.

4.4.2 Payload Carrier

Although the Spacelab pallet is the primary payload carrier considered in the study, several other options were evaluated. These alternate carriers have advantages for platform application, because the requirements are relaxed somewhat from the Spacelab sortie mission mode where payloads must operate in

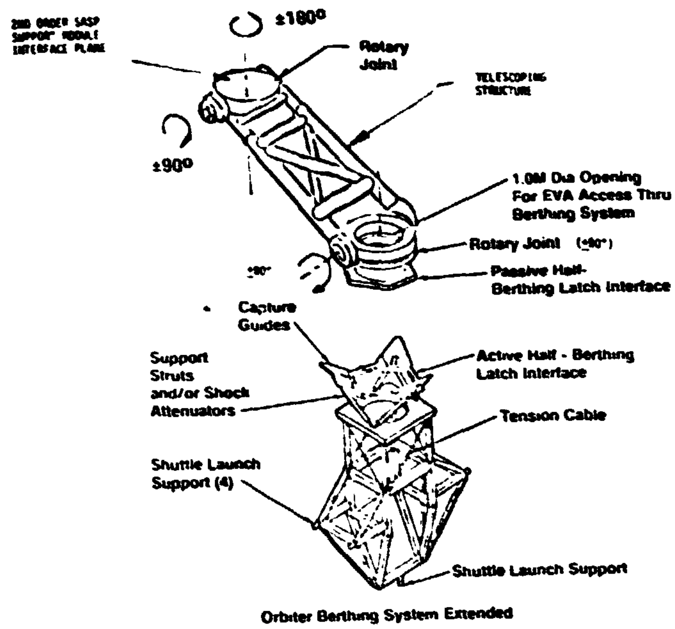


Figure 4.4.1-3 2nd Order Platform Berthing System

the Orbiter bay. This relaxation of requirements can result in designs which are lower cost, lower weight and are adaptable to many experiment viewing and packaging requirements.

4.4.2.1 Requirements Summary

Table 4.4.2-1 lists the primary requirements imposed on payload carriers for platform application.

4.4.2.2 Important Factors and Considerations

The payload carrier concepts investigated emphasized flexible experiment characteristics. Payloads mounted on the IPS with large viewing requirements were given prime considerations. Since the IPS is not designed to carry launch loads, it must be unlatched from the payloads during launch and engaged on-orbit. Also the load carrying structure must be unlatched from the payload on-orbit. These considerations suggest that a simpler, lower-cost, structural interface with the Orbiter may be desirable for SASP payloads.

- CARRIER DESIGN TO BE COMPATIBLE WITH ORBITER LONGERON AND KEEP FITTINGS
- CARRIER TO BE COMPATIBLE WITH ORBITER BOOST ENVIRONMENT AS DEFINED IN SPACE SHUTTLE SYSTEM PAYLOAD ACCOMMODATIONS HANDBOOK JSC 07700 VOL XIV, REVISION F.
- CARRIER TO INCORPORATE A PASSIVE BERTHING SYSTEM CONFIGURED TO INTERFACE WITH THE SASP ACTIVE INTERFACE MECHANISM.
- CARRIER TO PROVIDE MULTIPLE PAYLOAD ATTACH PROVISIONS TO ACCOMMODATE VARIOUS EXPERIMENT SIZES AND SHAPES.
- THE STRUCTURAL DESIGN SHALL PERMIT THE CARRIER TO ACCOMMODATE ANY WEIGHT EXPERIMENT WITHIN THE ORBITER CAPABILITY.
- THE CARRIER TO MINIMIZE WEIGHT AND THERMAL DISTORTION
- THE CARRIER CONFIGURATION SHALL MINIMIZE EXPERIMENT VIEWING OBSCURATION WHEN BERTHED TO THE SASP
- THE CARRIER CONFIGURATION TO MINIMIZE CARGO BAY VOLUME USAGE CHARGEABLE TO PAYLOAD.

Table 4.4.2-1 Payload Carrier Requirements

4.4.2.3 Work Accomplished

Several carrier options were defined and evaluated which are specifically designed for platform application.

4.4.2.3.1 Payload Carrier Options - The Spacelab pallet is designed for use in the Orbiter boost environment and is configured as not to impose viewing restrictions from the cargo bay. Since payloads are cantilevered from it, it is designed to sustain high bending moments and thus is heavy in terms of weight to payload supported. Payload mounting provisions designed for use with the SASP can be less complex, lighter, thermally compatible with SASP and minimize loads transmitted into Orbiter.

Several payload carriers are shown in Figure 4.4.2-1 in which experiments can readily be mounted for launch and satisfy their individual requirements

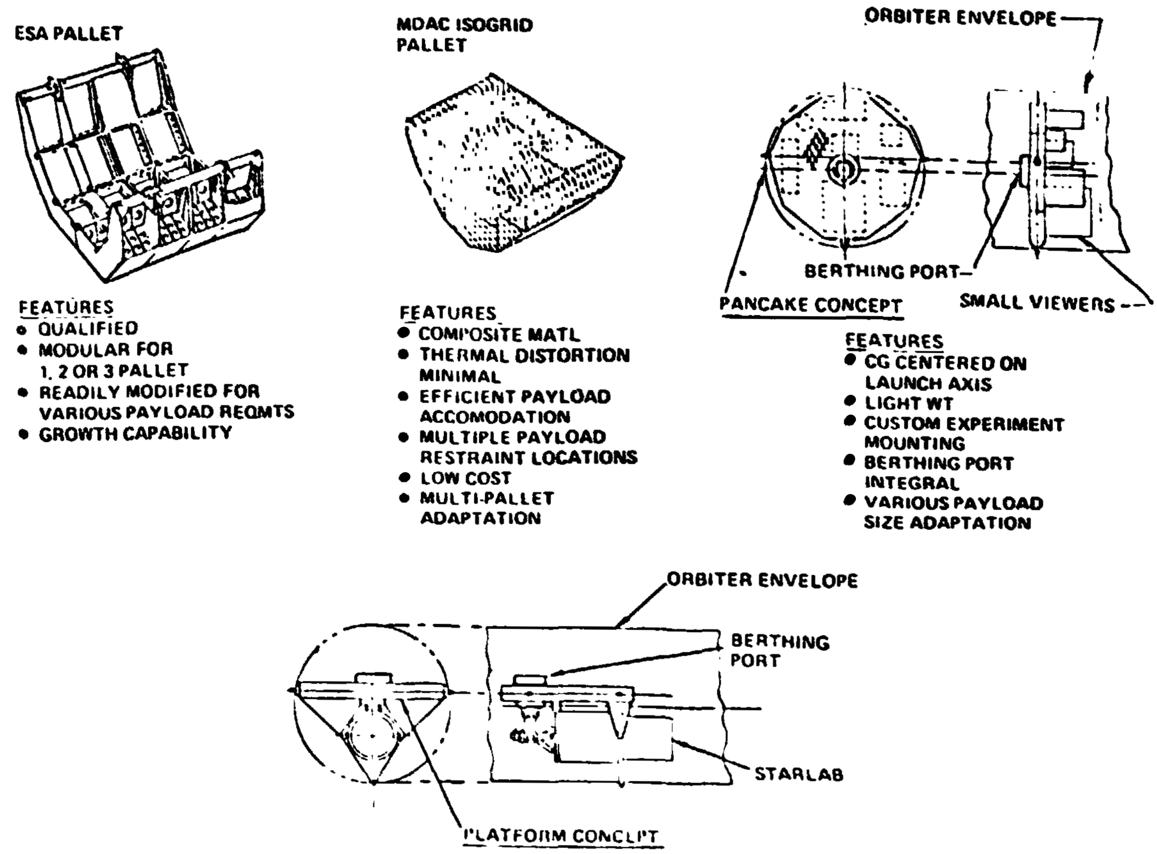


Figure 4.4.2-1 Payload Carrier Options

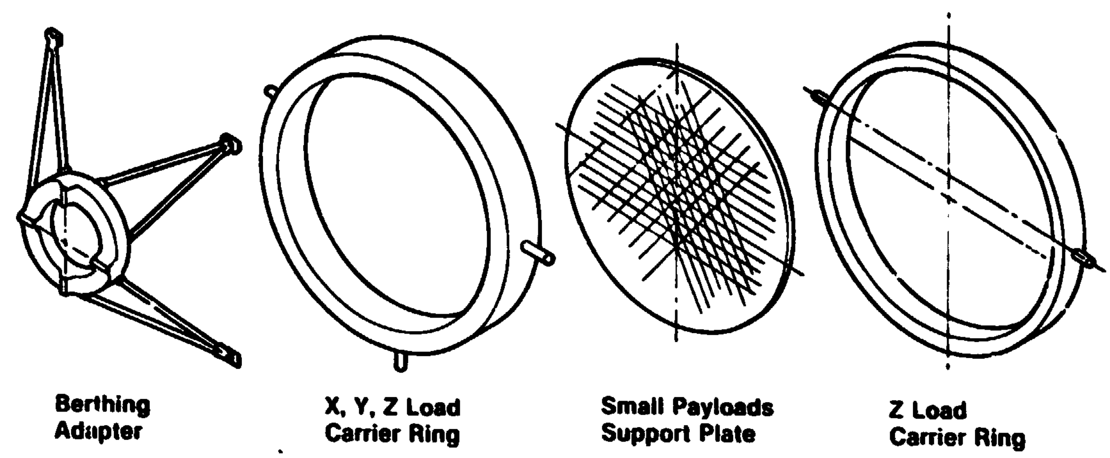
on a platform. Such carriers have program advantages, such as minimal viewing obscuration, lightweight, easily berthed to platform, and variable mounting pattern. They also maximize storage volume. The carrier can be designed to carry any weight within the limit of the Orbiter capability while the standard pallet has carry weight limitations. The MDAC isogrid pallet is similar in shape to the ESA pallet except it has unlimited mounting provisions and is lightweight.

The "Pancake" carrier concept provides a lightweight carrier for small experiment users. Isogrid structural design adds flexibility to accommodate various experiment sizes with custom mounting provisions to satisfy c.g. requirements.

The "Platform" concept provides a lightweight carrier designed for specific experiments. An example is shown in Figure 4.4.2-1. Sensors designed to operate free of the Orbiter need only a simple, lightweight type carrier configured to protect the experiment in the launch environment, be compatible with the SASP, and with the on-orbit payload operational parameters.

4.4.2.3.2 Advanced Payload Carrier Kit -The Spacelab pallet is designed to serve as a standardized structural interface between sortie mission payloads and the Orbiter. On sortie missions it is also the mounting platform for the IPS for those payloads requiring vernier pointing. Since the IPS is not designed to carry the launch loads that heavy payloads impose on the pallet, it must be unlatched from those payloads for launch and engaged on orbit requiring also that the load carrying structure be unlatched from the pointing payload on orbit. These considerations suggest that a simpler, lower cost, structural interface with the Orbiter may be desirable for SASP payloads. The Advanced Payload Carrier Kit concept, configured to provide an alternative to the Spacelab pallet for SASP payloads, is shown in Figure 4.4.2-2. The concept features four basic elements, (1) X, Y, and Z load carrier ring, (2) Small Payloads Support Plate, (3) Z load carrier ring, and (4) SASP Berthing Adapter.

4.4.2.3.3 "X", "Y", "Z" Load Carrier Ring - When the Spacelab pallet is used with pointing payloads on sortie missions, latches must be provided between the payload and its support structure which interfaces the pallet, and between the payload and the IPS, as described in the preceding discussion. Since these latches require hardwire interfaces for power and signals, they complicate the pallet. When the pallet is used for SASP pointing payloads, these latches and interfaces must be retained and berthing latches and umbilical added for interfacing the pallet with the Platform.



Features

- **Low Cost and Lightweight**
- **Optimized for Payloads Which Do Not Have To Operate in Cargo Bay**
- **Well-Suited for IPS Mounted Payloads (Example SIRTF)**
- **Minimum Pointing Restriction for Gimbaled Payloads**
- **Minimum Weight on Platform**

Figure 4.4.2-2 Advanced Payload Carrier Concept

With the carrier ring concept shown in Figure 4.4.2-3, all latches between the pointing payload and its support structure are eliminated as well as the latches between the IPS and the payload. Provisions for berthing to the Platform are incorporated in the IPS and the IPS, with those provisions, is supported from the payload for launch.

This arrangement is considerably simpler than that with the Spacelab pallet because of the elimination of latches and power and signal distribution from the support structure which is completely passive. Because of the loading symmetry, it is also more efficient structurally, and therefore, lighter than the Spacelab pallet.

4.4.2.3.4 Small Payloads Support Plate - On some sortie missions, a number of payloads are supported from a plate mounted on secondary structure on a single pallet. To accommodate payloads of this type on the SASP, the beam

stiffened machined isogrid plate shown in Figure 4.4.2-4 was configu for use in conjunction with the payload carrier ring shown in Figure 4.4.2-3. Because of the symmetry of the support provisions, this configuration is more efficient structurally than the Spacelab pallet and is therefore lighter. While use of the Spacelab pallet for fixed SASP payloads is much less complicated than for pointed payloads, the structural simplicity reduced cost and weight savings potential make this concept attractive.

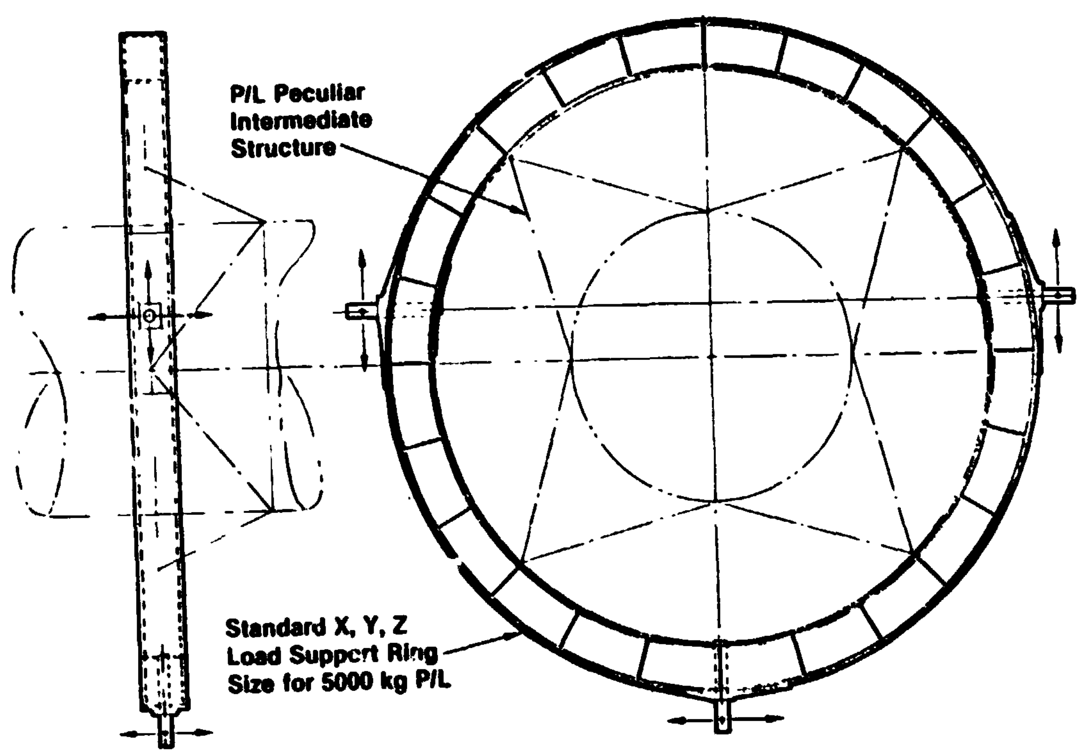


Figure 4.4.2-3 Payload Carrier Ring Concept

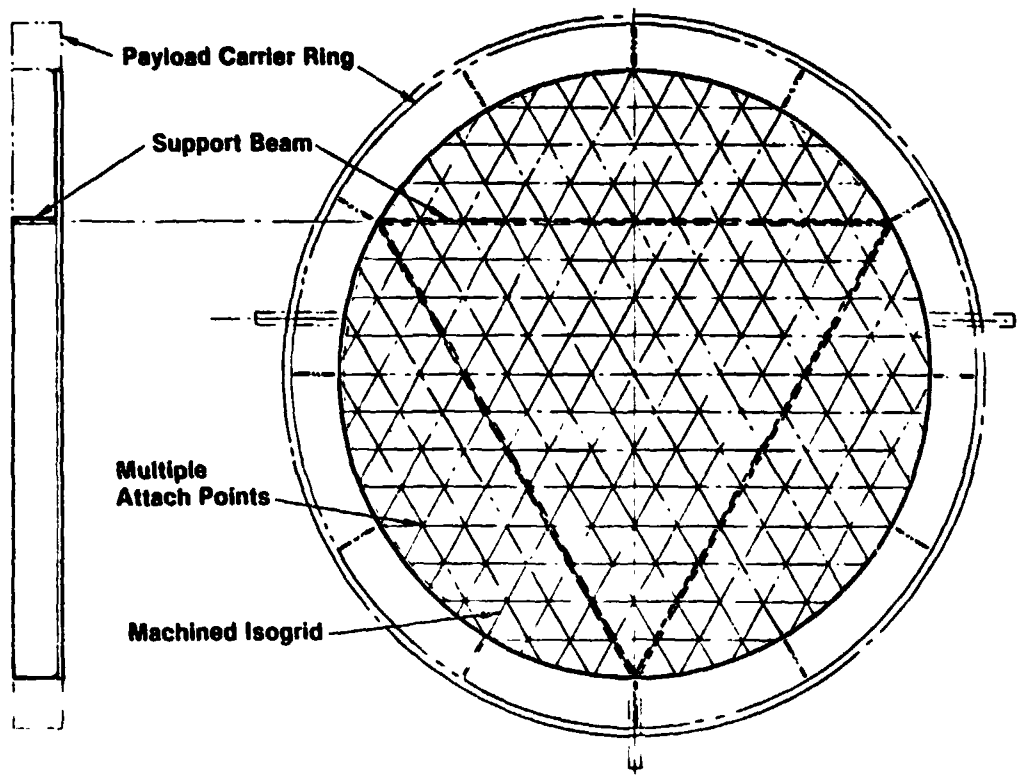


Figure 4.4.2-4 Multi-Small Payloads Support Plate

4.4.2.3.5 "Z" Load Carrier Ring - The "Z" load carrier ring is identical to the ring designed shown in Figure 4.4.2-3 with the "Y" fitting removed. This ring is supplied for payloads requiring additional longeron support during launch.

4.4.2.3.6 SASP Berthing Adapter - The interface with the SASP for pointed payloads launched with the payload carrier ring is through the IPS, as described earlier. But for fixed payloads mounted on the isogrid support plate on the carrier ring, as shown in Figure 4.4.2-1, an adapter is required for berthing the support ring to the Platform. The berthing adapter shown on Figure 4.4.2-5 is configured to meet this requirement. It can be used for large payloads, or multiple small payloads mounted on a support plate, which can tolerate a fixed orientation relative to the Platform.

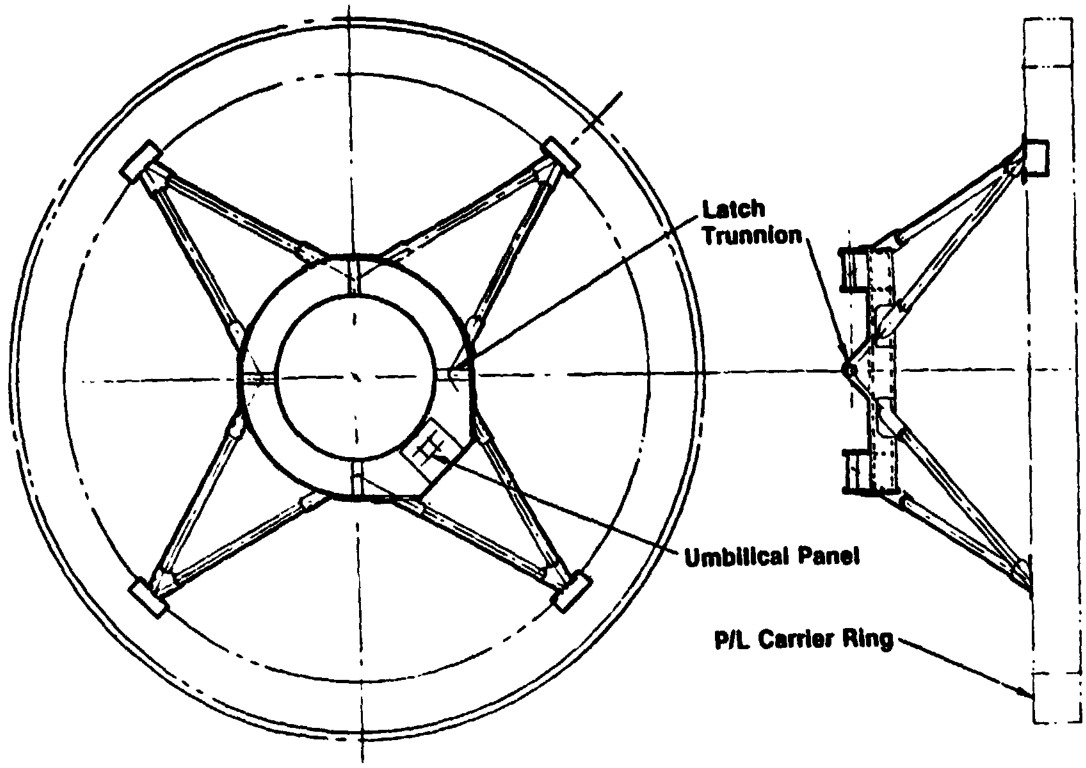


Figure 4.4.2-5 Berthing Adapter Payload Carrier Ring

4.4.2.3.7 SIRTF with Advanced Payload Carrier Kit - The launch configuration shown in Figure 4.4.2-6 was selected to illustrate the use of the carrier ring concept with a payload which is a candidate for inclusion on a SASP mission. Berthing provisions are located on the base of the IPS and on one carrier ring supporting the tank cluster. The IPS is berthed on a port on one side of the Platform and the tank cluster is berthed at the port directly opposite. Insulated lines for cryogenic helium run from the powered umbilical at the tank port to the power umbilical at the IPS berthing interface for delivery of cryogenic helium to the payload. This arrangement appears lighter, simpler, and therefore, lower cost than the use of two Spacelab pallets.

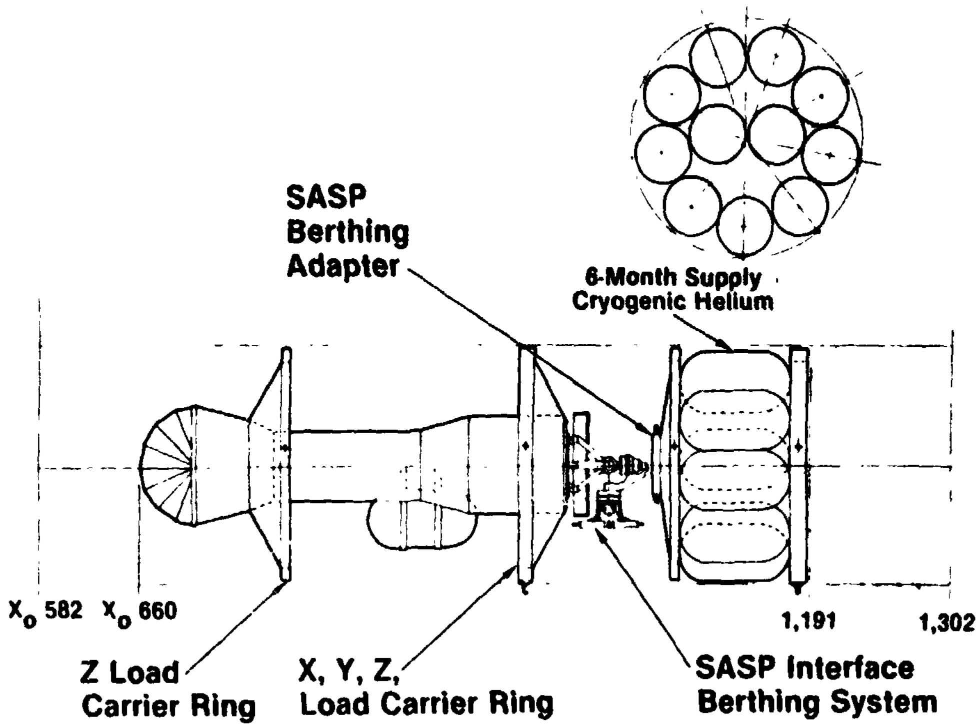


Figure 4.4.2-6 SIRTF with Advanced Payload Carrier

4.4.2.^ Conclusions and Comments

A comparison of the various payload options results in the following conclusions.

- Experiments designed to operate free of the Orbiter need only a simple, lightweight carrier designed to protect the experiment in the launch vironment. A suitable ring-type has been developed in this study. ... wide range of payload types, sizes, and requirements indicated that a modular carrier designed compatible with all types of payloads may be the most economical for the SASP applicatior
- The Spacelab pallet is designed for use in the Orbiter and is configured as not to impose viewing restrictions from the cargo bay. It is designed to sustain high vending moments and thus is heavy in terms of weight to payload support... SASP payload carriers can be less complex, lighter, and still thermally compatible with SASP.

4.5 THERMAL CONTROL SYSTEM TRADES

Trades were performed at various levels which led to the selected subsystem concept. The higher level trades impacted other subsystems and have a significant impact on overall program cost, schedule, and implementation. An example at this level is the trade between centralized heat rejection versus pallet located heat rejection. Results of this trade can have a significant impact on pallet and platform design.

Lower level trades impacted interface designs, subsystem configurations, and detailed configurations and arrangements of subsystem equipment.

4.5.1 Requirements Summary

The thermal control subsystem must provide cooling to each docked payload amounting to 5 kW sustained and 9 kW peak. The 5 kW sustained load is a nominal value and corresponds to a payload pointing to a relatively warm environment such as solar observation or earth viewing. Under these circumstances the amount of heat loss passively is expected to be small. Depending upon the specific payload design and orientation, significant amounts of electrical heat could be lost directly to space and not show up in the radiator loads. If the full electrical distribution design power of 6 kW is directed to the payload, at least 1 kW will have to be provided in the nominal case. However, flexibility is a design goal so that cooling needs to each port can be increased and decreased based on the requirements of the payload complement being flown. Platform subsystem must also provide cooling to subsystem equipment. Total maximum cooling load is 25 kW which equals the sustained power supplied by the Power System.

Both payload and subsystem equipment cooling temperature requirements are 60°F payload supply and 110°F return. Life Science and manned modules require

a 40°F supply. Higher temperatures are allowable for many high power payloads and for transient conditions but specific requirements are dependent upon the particular payload.

4.5.2 Important Factors and Considerations

Primary goal for performing thermal control subsystem trades is to offer ample and flexible cooling resources to experimenters using the Platform. The design must be low cost consistant with this goal and must not represent development risk. One way this can be accomplished is to make maximum use of existing technology and hardware.

The design must be capable of operating reliably for a 10 year lifetime while presenting no safety hazards to crew and associated systems. The platform design must be compatible with interfacing systems, especially the Orbiter and Power System.

4.5.3 Work Accomplished

Five key trades were performed on the SASP study which had a significant impact on the selected thermal control subsystem design. These trades were as follows.

1. Payload arrangement - parallel or series and loop arrangement
2. Payload interface options
3. Centralized radiator dual loop alternates
4. Centralized radiator flow options comparison
5. Centralized versus pallet radiator

The trades were performed in the sequence shown above because the first four trades generated a centralized radiator concept to be traded against the pallet radiator concept as performed in the last trade.

4.5.3.1 Loop Arrangement - Parallel or Series

The platform cooling loop can be arranged to pass through the payloads in either a series or a parallel arrangement as illustrated by the simple schematics given in Figure 4.5.3-1. Each of these options have specific advantages and disadvantages which the figure summarizes.

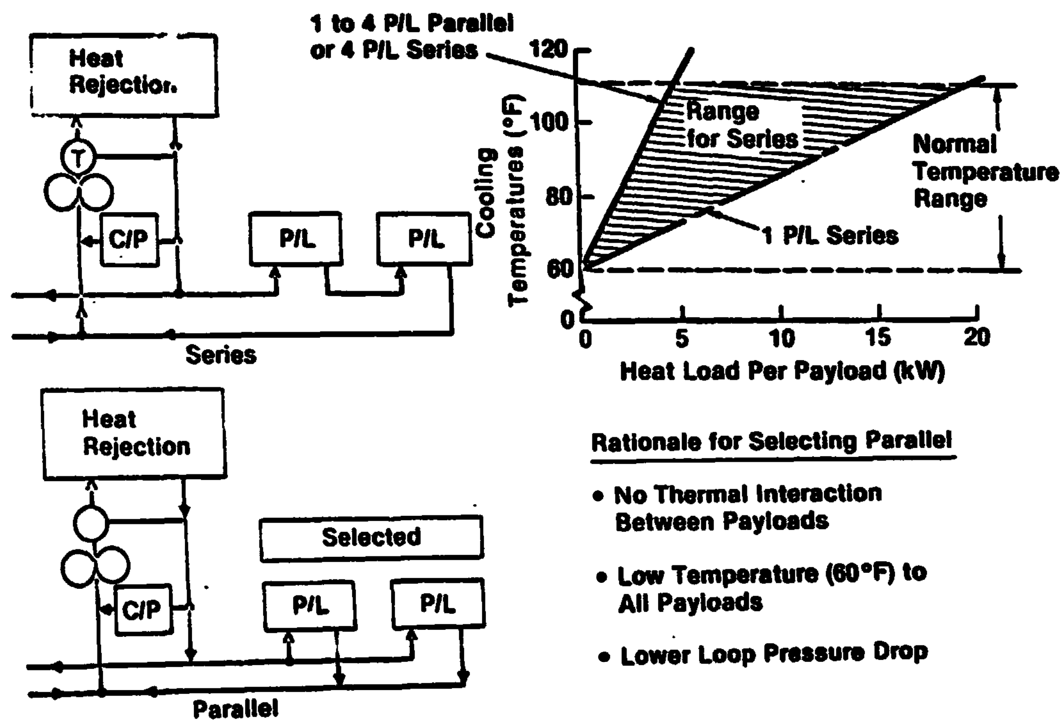


Figure 4.5.3-1 Payload Arrangement Options Parallel or Series Flow Through Payloads

Performance in terms of cooling temperatures are shown in the figure on the upper right. All payloads in the parallel arrangement will have the same inlet temperature and for the same heat load they will all have the same outlet temperature. Based on platform requirements, the temperature range for 5 kW heat loads in parallel will be 60 to 110°F. This is based on the total platform fluid flow being divided equally to each payload.

On the other hand, series arranged payloads have the total platform fluid flow through the payloads in sequence. The first payload in the flow sequence will have a 60°F inlet temperature and because of the high fluid flow rate, a very large cooling load can be accommodated. However, downstream payloads will not have a higher inlet temperature. Any variations in upstream heat load will perturbate loop temperatures in downstream payloads.

An additional disadvantage of the series arrangement is due to the higher pressure drop of flowing the full fluid flow through all payloads. A pressure drop analysis shows that use of the series arrangement would preclude the practical use of available Orbiter/Spacelab hardware.

Because of pressure drop considerations and thermal interaction between payloads of the series arrangement, the parallel concept was selected.

4.5.3.2 Payload Interface and Loop Arrangement Options

Several competing options were considered with regard to the interfacing method with the payload and the number and arrangement of loops. Figure 4.5.3-2 depicts two direct interfacing options and two options employing a heat exchanger interface.

The two-loop split system, shown in the upper left, has a separate loop interfacing directly with two of the payloads. Each loop would service one arm in the case of the crossarm configuration. An improvement on this option employs a separate loop for each payload, thereby improving system survivability. This approach substantially increases costs and complexity.

Heat exchanger interfacing options can use a separate heat exchanger for each payload or two payloads can be interfaced with a single heat exchanger with dual passages, see the bottom right figure. The later arrangement is less costly if the ports are relatively close together.

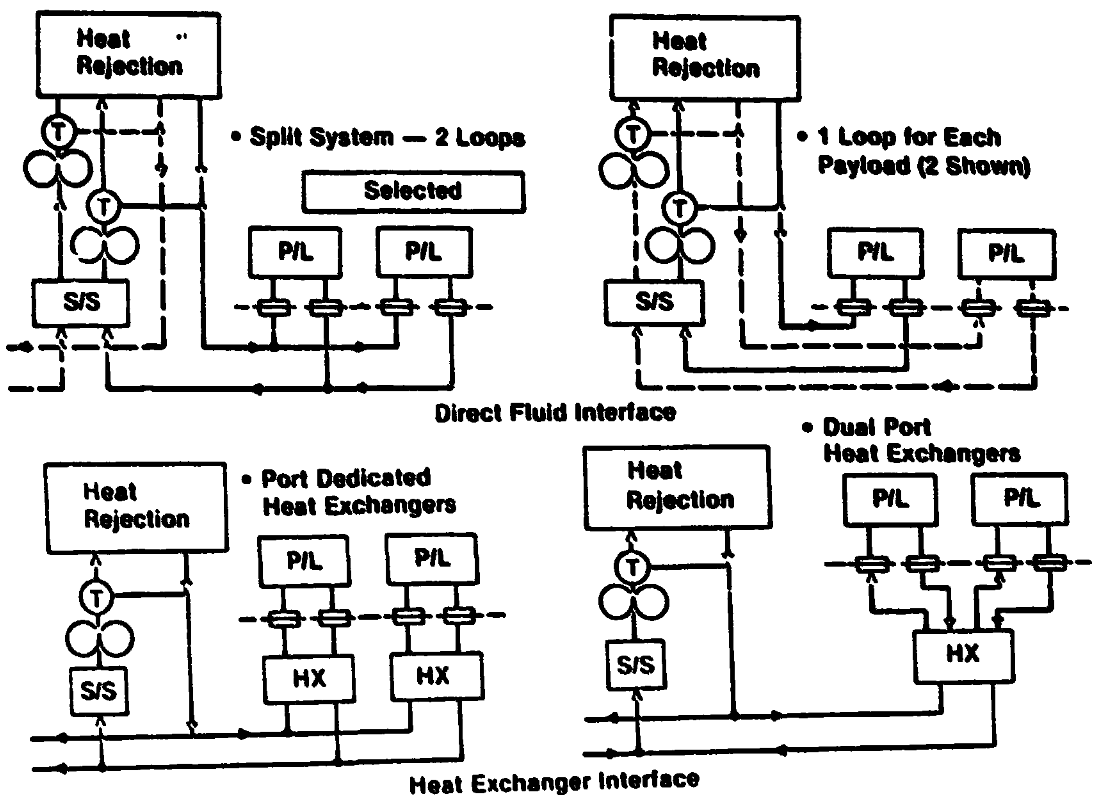


Figure 4.5.3-2 Payload Interface and Loop Arrangement Options

Table 4.5.3-1 compares interface and loop arrangement options with regard to key selection criteria. Only the dual port interfacing heat exchanger option is included in the table because it will be favored in most cases over the port dedicated option because of simplicity and cost.

A number of major hardware elements are related (in terms of equivalent pump packages) to the cost of the thermal control subsystem. These are given in the table for the Platform, the pallet, and totals. Results show that the split system has the fewest platform units and total units and equals the fewest pallet units.

A cursory reliability assessment shows that this parameter does not differ greatly between options. The option employing one loop for each payload has the highest reliability for each payload (0.98) because a limited number

Criteria	Fluid Interface: Split System	Fluid Interface: One Loop for Each Payload	HX Interface: Dual Port HX
Major Hardware Elements (Equivalent Pump Packages)			
— Platform	3.26	6.37	4.26
— Pallets (Payloads)	1.11	1.11	8.11
— Total	4.27	7.48	12.37
Reliability (1 year)			
— Each Payload	0.95	0.98	0.95
— All Payloads	0.95	0.93	0.92
Failure Impact			
— Loss of Platform	2 Ports Lost	1 Port Lost	40% Reduction in Performance
— Loss of Pallet	2 Ports Lost	1 Port Lost	1 Payload Lost
Method of Repair			
— Platform Fluid Loss	EVA (Ground)	EVA (Ground)	EVA (Ground)
— Platform Mechanical	EVA (Ground)	EVA (Ground)	EVA (Ground)
— Pallet System	Ground (EVA)	Ground (EVA)	Ground (EVA)
	SELECTED		

Table 4.5.3-1 Payload Interface and Loop Arrangement Options Comparison Summary

of components must operate successfully for this option. The heat exchanger interface reliability for all payloads operating successfully is the lowest, (0.92), because two platform fluid loops and four pallet loops need to operate successfully for this condition. Other cases fall between these values.

The fluid interface and heat exchanger interface options differ regarding survivability. Loss of either platform or pallet loops will cause loss of two ports in the split system and one port in the option having one loop per payload. The heat exchanger interface option is less vulnerable, loss of a platform loop causes about 40% reduction in performance at each port and a parallel loop loss only effects that payload.

Most failures of platform components are expected to be repairable by EVA. Some failure types could require ground return for repair. The primary mode of repair for the pallet system will be ground return for repair, however, minor repairs might be made by EVA.

Based on the much lower cost and good reliability the split system is selected. However, to improve survivability it is recommended that both top and bottom ports on the configurations be supplied with cooling fluid connections with valves to select top, bottom, or both ports and also to isolate ports in the event of a failure. Both top and bottom ports can be cooled at one time; however, a reduction in cooling capacity will result in reduced flow to each port.

4.5.3.3 Centralized Radiator Dual Loop Alternatives

The trade in the previous paragraph called, "Payload Interface and Loop Arrangement Option", resulted in the selection of a split system where a separate loop services each arm. This concept which could also be called "Dual Loop", forms the basis for the trade described in this paragraph which trades options for arranging the two loops on the four radiator panels corresponding to four sides of platform standoff surfaces.

The concept using separate panels, shown on the left of Figure 4.5.3-3, merely directs one loop through two of the panels while the second loop flows through the remaining two panels. Manifolding is simple for this alternate, only one is required at each end of the panel.

The other two concepts, center and right of this chart, result in both loops flowing through all panels. The alternate tube concept arranges the flow so alternate tubes are used by each loop. The adjacent tube concept has tubes

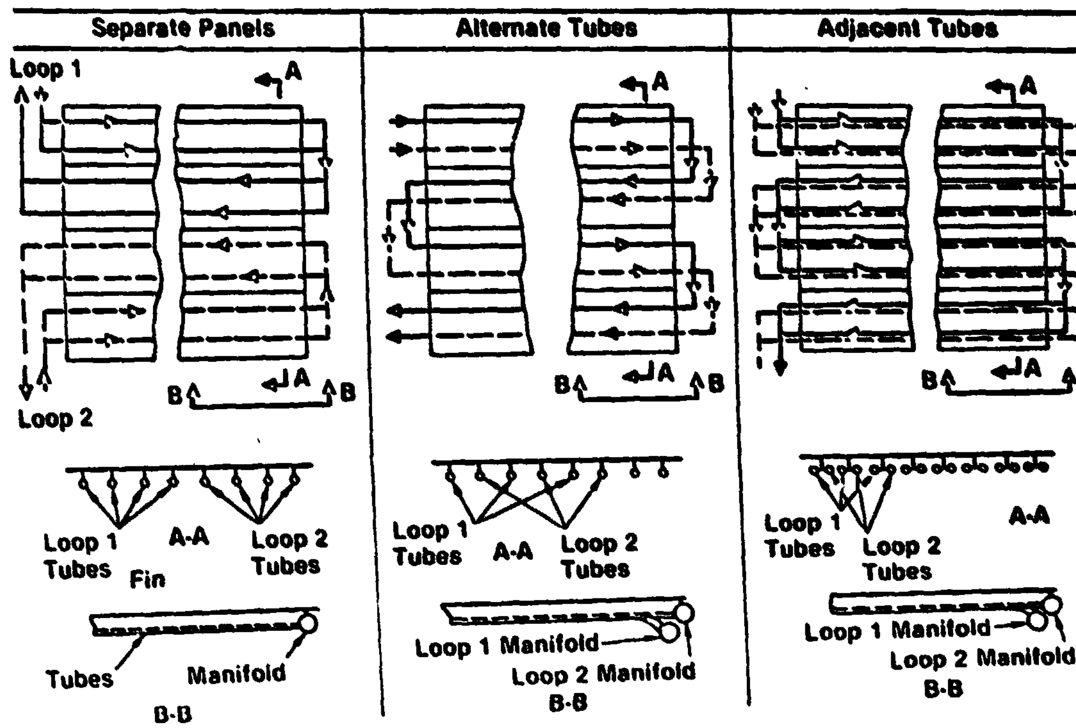


Figure 4.5.3-3 Centralized Radiator Dual Loop Alternates

from both loops sharing a standoff web. Both of these concepts have relatively complicated manifolding requiring two at each end, tubes would have to be bent to line up with one of the manifolds.

A comparison of the alternates is shown in Table 4.5.3-2. The separate panel concept has a greater reduction in performance if one loop is inoperative because performance from two entire panels would be lost. However, this performance would not normally be usable because Freon flow in the remaining operative loop would have to be increased to take advantage of better one-loop-out performance for the alternate tube and adjacent tube concepts.

Some advantage also exists for the alternate tube and adjacent tube concepts regarding environment averaging. Since each loop runs through all four panels, the heat rejection performance will be based on an average of all four sides. Only two-sided averaging results with the separate panels concept.

Criteria	Separate Panels	Alternate Tubes	Adjacent Tubes
One-Loop-Out Performance	50% Reduction*	14% Reduction with Adequate Flow	Slight Reduction with Adequate Flow
Number of Manifolds	$\boxed{1}$	2	2
Manifold Complexity	168 Tube Welds No Tube Bending	168 Tube Welds 1/2 Tubes Bent	336 Tube Welds 1/2 Tubes Bent
Environment Averaging	Two-Sided	Four-Sided	Four-Sided
Load Averaging	None	Small	100%
Vulnerability of Losing Both Loops	Small	Manifolds Vulnerable	Manifolds and Tubes Vulnerable
Weight (lb)	1,126	1,135	1,221

*Greater Performance Probably Not Utilized

Table 4.5.3-2 Centralized Radiator Dual Loop Alternate Comparison

The separate panel concept was chosen for the centralized radiator design primarily because of fewer and simpler manifolds which have a strong impact on cost. It is believed that these factors outweigh the advantages of the more complex designs.

4.5.3.2 Centralized Radiator Flow Options Comparison

This trade compares the flow arrangement between panels, i.e., parallel or series and the number of fluid passes in each panel. Two typical arrangements are shown in Figure 4.5.3-4.

Table 4.5.3-3 gives a comparison of flow options for panels arranged in series and parallel with various numbers of passes. The option of panels in series with four passes per panel was selected because of lowest area requirements and weight. However, the pressure drop for this option is high and for the final design, tube size was decreased to reduce pressure drop to a lower level.

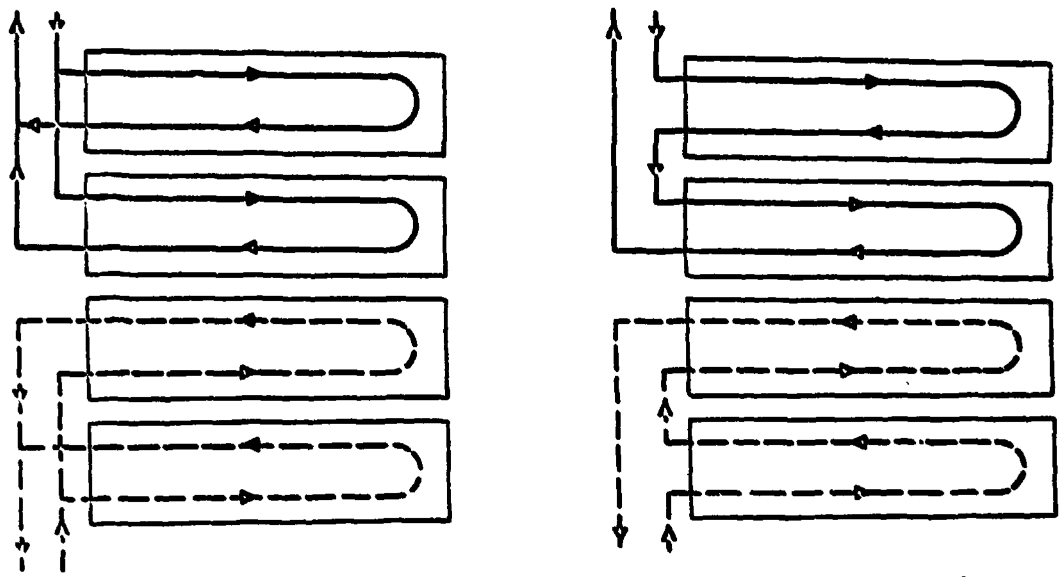


Figure 4.5.3-4 Centralized Radiator Flow Options

Characteristic	Panels in Series		Panels in Parallel		
	Two Passes per Panel	Four Passes per Panel	Two Passes per Panel	Six Passes per Panel	Ten Passes per Panel
Area (sq ft)	603	588	682	625	612
Fixed Weight (lb)	1,157	1,126	1,282	1,159	1,131
Fluid Weight (lb)	37	30.5	81.5	42.5	35.3
Pressure Drop (psid)	5.9	39	0.15	2.83	11.3
Pump Power (watts)	56	374	1.4	27.1	106.4
Fin Efficiency (%)	95.5	95.5	95.6	95.5	95.5
Reynold's Number	8,810	17,600	2,200	6,608	11,000
Fluid to Root ΔT (°F)	8.9	6.9	19	12	10.1

Selected Arrangement
Reduce Pressure Drop

Table 4.5.3-3 Centralized Radiator Flow Options Comparison

4.5.3.5 Centralized Versus Pallet Radiator

The subsystem trades described above resulted in a selected centralized radiator design to be traded against the pallet concept. Both of these competing designs were optimized to obtain optimized designs to ensure a valid trade.

The pallet system, shown in Figure 4.5.3-5, consists of four pallet radiators, a pump package, temperature control valve, and four radiator panels located in parallel. Freon 21 is circulated in the loop which delivers 60°F fluid to cold plates mounted to subsystem and payload avionics. Temperature control is accomplished by passing some portion of flow around the radiators to obtain the required mix temperature. One of these subsystems must be provided for each pallet system being flown or in ground processing.

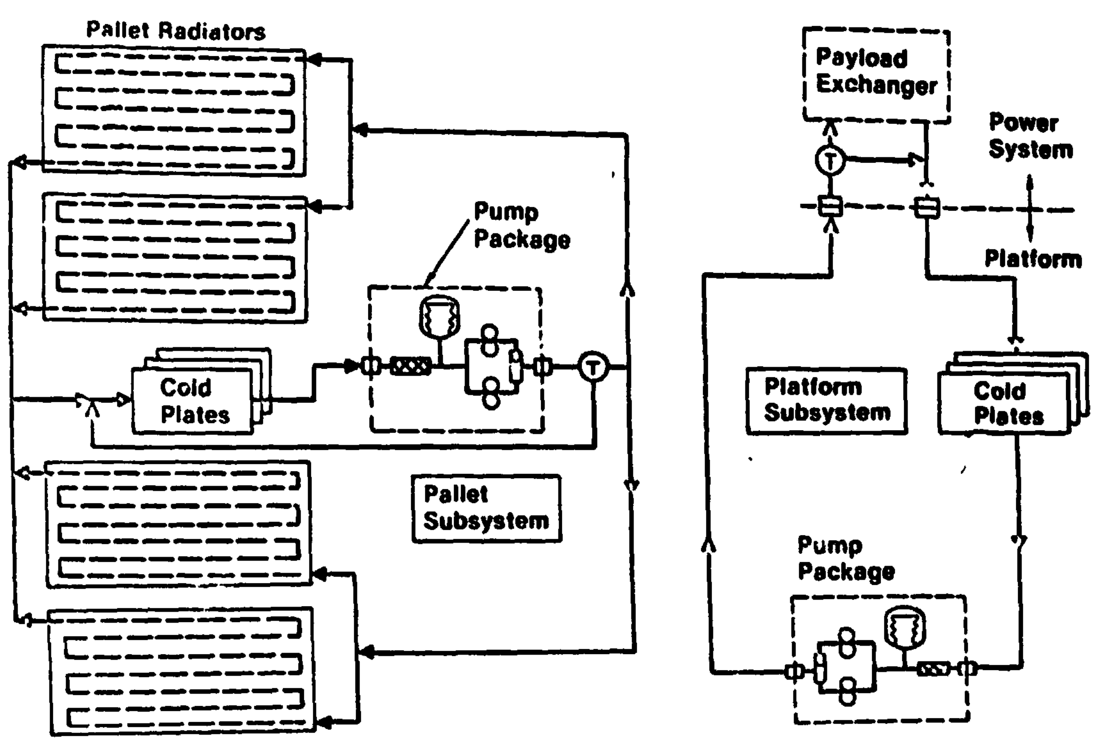


Figure 4.5.3-5 Platform Thermal Control
Pallet Located Radiators

The platform subsystem shown on the right interfaces with the Power System for heat rejection and fluid temperature control. A pump package circulates Freon 21 from the Power System payload heat exchanger to cool cold plate mounted platform avionics.

Figure 4.5.3-6 shows the design details of the pallet radiator concept to be traded against the centralized concept. The four outside pallet surfaces are used to mount the radiators. Radiator tubes are mounted on the spaceside of the fin sheets to prevent infringement of the pallet radiators into the Orbiter bay envelope during launch and reentry. This tube location is not an efficient design for meteoroid protection but a 0.99 probability of no puncture per panel is achieved with 0.20 inch thick tube walls.

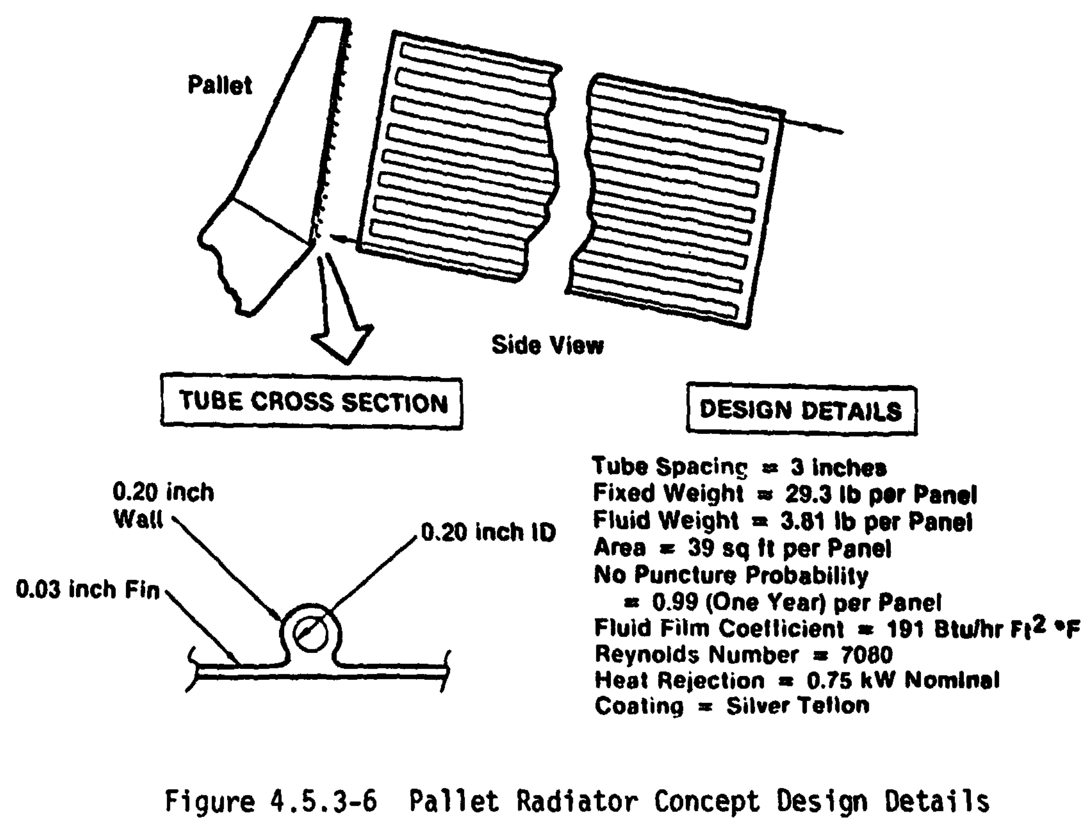


Figure 4.5.3-6 Pallet Radiator Concept Design Details

The Reynolds number of the circulating fluid is 7,080 which is well within the turbulent flow range to minimize fluid to tube wall temperature drop while retaining a reasonable pressure drop.

Table 4.5.3-4 summmarizes the comparison between pallet located radiators ?? the centralized concept. Key comparison criteria were developed for the competing concepts and these are shown in the table.

Criteria	Centralized	Pallet
Hardware Requirements		
- Pumps	2 Packages	2 Packages Platform 1 Package Each Pallet
- Disconnects	2 Each Port +2	2 for PS Interface
- Temperature Control Valve	2 for Platform	1 Each Pallet
- Radiator Panels	4 for Platform	4 Each Pallet
Reliability (One Year)		
- One Payload	.926	0.937
- All Payloads	0.830	0.819
Failure Impact		
- Loss of Platform Loop	One Arm Lost	Both Arms Lost
- Loss of Pallet Loop	One Arm Lost	One Payload Lost
Cooling Available per Payload	5 kW (Accommodates 86% of Data Base)	2.6 to 3.0 kW for Fixed Radiators (Accommodates 72% of Data Base)
New Development	Disconnects	None

Table 4.5.3-4 Centralized Versus Pallet Radiator Comparison Summary

Hardware requirements differ significantly between the competing concepts. The pallet radiator concept requires more pump packages, temperature control valves, and radiator panels because each pallet is, in effect, a self-contained system. However, complexity of the pallet radiators and pump package are expected to be somewhat simpler than for the Platform. Key to the Platform System are the large number of fluid disconnects which must be used each time a payload is changed out.

Performance for the centralized system is higher, 5 kW nominal, because available fixed pallet surfaces limit heat rejection to about 2.6 to 3 kW per pallet. Deployable pallet radiators were not considered because of cost, complexity and experiment interference.

Based on the lower hardware requirements and higher performance, the centralized concept is tentatively selected for the purpose of developing programmatic data. However, due to the criticality of the fluid disconnect and because of lack of payload data on heat loss directly to space, further, more detailed study is recommended in follow-on effort.

4.5.4 Conclusions and Comments

The key trades performed in the thermal control area are summarized in Table 4.5.4-1. These trades formed the basis for arriving at optimum designs for the two main competing options of centralized platform radiator and pallet located radiators. These two options were compared and the centralized concept was tentatively selected because of higher performance and reduced hardware requirements. The pallet concept can reject only about 3 kW of heat which is about half of the sustained electrical power supply capability. Some heat may be lost directly to space from pallet located equipment by passive means. However, it is felt that limiting cooling to 3 kW would place severe design restrictions on the user.

Use of the pallet radiator concept offers reduced flexibility in accepting specialized payload carriers such as the ring concept. Many of these carriers will not have adequate flat surfaces and structural block and may drive radiator heat rejection.

TRADE	SELECTED CONCEPT	RATIONALE
Centralized versus Pallet Radiator	Centralized	• Higher Performance • Less hardware
Loop Arrangements - Parallel or Series	Parallel	• No interaction between payloads • Low temperature supply • Lower pumping requirements
Payload Interface Options	2 Loops with direct fluid interface	• Less hardware
Centralized Radiator-Dual Loop Alternates	Separate panels	• Low weight • Low complexity • Low meteoroid vulnerability
Centralized Radiator Flow Options Comparison	Panels in series - 4 passes per panel	• Highly efficient • Low weight • Acceptable pressure drop

Table 4.5.4-1 Key Thermal Control Subsystem Trades

Another advantage of the centralized concept is the reduced hardware requirements. The centralized concept uses two pump packages wherein a pump package is required on each pallet for the pallet radiator concept.

A major disadvantage of the centralized concept is due to the requirement for cooling fluid connections to be made in space. This requirement is similar to the current Power System design which has three disconnect sets to allow use of the Power System payload heat exchanger. Therefore, it is believed that the same basic disconnect which is developed for Power System will also find application on the Platform.

4.6 PAYLOAD CRYOGENIC PROVISIONS

4.6.1 Overview

A review of payload requirements indicates a large number of payloads requiring cryogenics, but insufficient data are available for detailed

engineering trades and studies. One payload which has the cryogenic requirements defined in detail is the SIRTF which requires 4930 liters of supercritical helium four times a year. This must be supplied to instruments mounted on an IPS which precludes transfer of cryogen from a central supply. Therefore, a centralized platform system cannot satisfy the SIRTF requirements.

A centralized concept must be replenished by tank replacement or refill. Refill approach would require some means of fluid phase control such as a passive screen device, under development, or settling forces which would require operational constraints. This approach also is somewhat inefficient because of ullage and line loss.

Specific payload cryogenic requirements are not defined in sufficient detail at this time to merit serious consideration of a platform supply system. Therefore, a payload-provided croygenic supply concept is recommended, as listed in Figure 4.6.1-1.

SUBJECTS STUDIED

- Payload Requirements
- Candidate Approach Definition
- Tradeoff of Platform Supply System Versus Payload Provided Concept

CONCLUSIONS

- Minimal Detailed Data Available on Payload Requirements
- Passive Cryogenic Cooling Designs Call for On-Orbit Fluid Transfer for Replenishment
- Subcritical Fluid Transfer Requires Settling Forces or Passive Screen Device
- Tank Replacement Eliminates Transfer System and Fluid Losses/Residuals (Concept presented at Mid-Term)
- Cryogenic Fluid Lines Cannot Be Routed Around European IPS or Sperry ASPS
- Payload Provided Cryogenic Supply Concept Recommended

Figure 4.6.1-1 Platform Cryogenic Provisions

4.6.2 Currently Defined Cryogen Requirements

The payload cryogen requirements "Data Bank" (see Figure 4.6.2-1) which is required to design the cryogenic supply system is very sparse as this figure illustrates. The four payloads with defined cryogen quantities were used to size the tanks. The different types of cryogen (i.e., helium, nitrogen) and the different states (i.e., superfluid helium, subcritical, supercritical, solids) make it extremely difficult to provide a single tank design. A modular tank system can provide the desired quantities and with proper flow control of the vapor cooled shield vent gases, a single tank design based on helium properties could possibly contain the other cryogens. Figure 4.6.2-2 illustrates the various approaches to providing payload cooling with cryogens.

PAYLOAD CODE	TYPE OF CRYOGEN	QUANTITY	RATES	PAYLOAD LIFETIME	COMMENTS
AST 1	SUPERFLUID HELIUM	380ℓ (~30 kg)	10/DAY NOM DESIGN MAX	~1 YEAR	CRYO RESUPPLY EVERY 90 DAYS INSTRUMENT NOT DAMAGED IF CRYOGEN IS DEPLETED
SIRTF (FREE FLYER)	SUPERCRITICAL HELIUM	[illegible] SC (1176 kg)	--	6 MONTHS	DETECTOR AT 10K
HE 2	TBD	--	--	-	--
AST 3	TBD	--	--	4 YEARS	--
SP 6	SOLID	-	--	~1 YEAR	50 W COOLING AT 100K USING SELF CONTAINED TWO-STAGE SOLID CRYOGEN
HE 4	TBD	--	--	1 TO 2 YEARS	--
AOI 2	TBD	-	--	--	CRYO AT 12 MONTH INTERVAL
HE 10/11	TBD	--	--	>2 YEARS (UP TO 10 YEARS)	30 W AT 100K CRYOGENICS OR ACTIVE REFRIGERATION
AMPS 8	LHE	--	--	--	CRYO AT 12 MONTH INTERVAL
HE 3	LHE	-	--	--	MAY HAVE LARGE SUPER CONDUCTING MAGNET
SPP 2	TBD	--	--	>2 YEARS	--
R 7	LN_2	--	--	--	HAS LN_2 DEWAR
AST 4	TBD	--	--	>1 YEAR	CRYOGENS NEEDED AT DETECTOR
SPP 3	TBD	--		1 YEAR	--
AOI 1	TBD	--	--	--	CRYO RESUPPLY
ADD CRO	TBD	--	--	>5 YEARS	--
CRM	TBD	-	--	REUSABLE	--
SUBSAT	TBD	--	--	REUSABLE	CRYO IS MISSION DEPENDENT
AGRA	TBD	--	- -	~1 YEAR	--
IR TEL	LHE	-	--	~1 YEAR	ONE VISIT PER YEAR MAY BE REQUIRED TO REPLENISH CRYOGENS
LS/LAP	TBD	-	--	7/10 YEARS	-
LUAB	TBD	-	--	7/10 YEARS	--
LOL AMD	TBD	--		7/10 YEARS	--
RELATED DATA					
HEAO B	LIQUID HELIUM	3000ℓ (410 kg)		1 YEAR	SUPERCONDUCTING MAGNET
IRAS	SUPERFLUID AND SUPERCRITICAL HELIUM	540ℓ SF (70 kg) 54ℓ SC (6 kg)		1 YEAR	SF AT 1.85K SC AT 6.2K

Figure 4.6.2-1 Currently Defined Cryogen Requirements

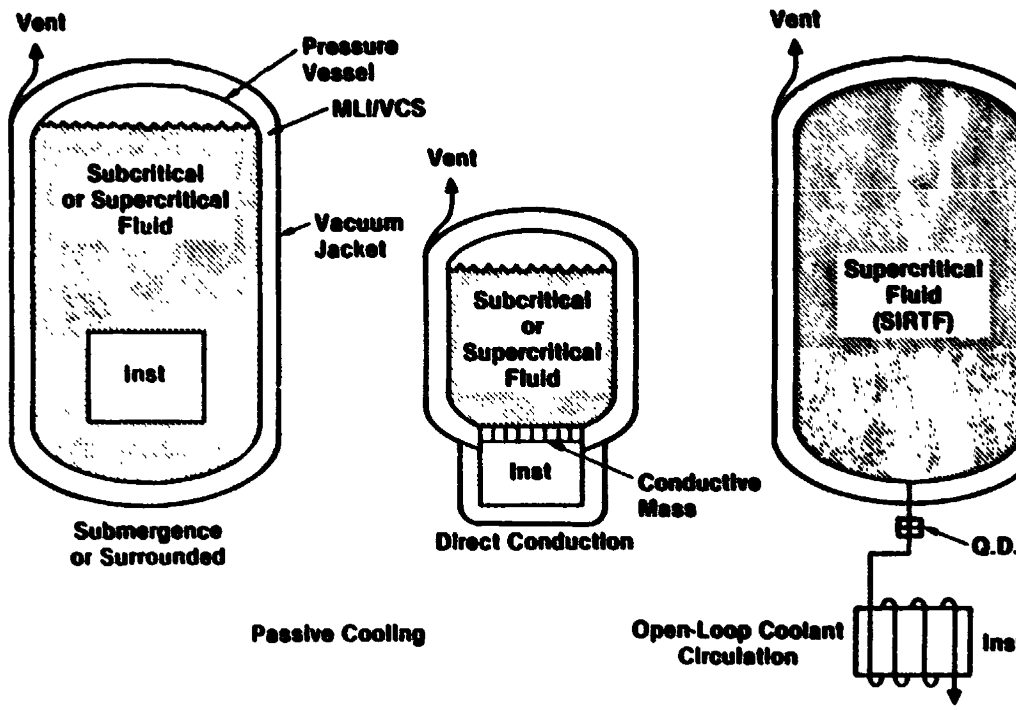


Figure 4.6.2-2 Payload Cooling Concepts

This chart illustrates the cooling concepts available to the experimenter. Passive cooling is further divided into instrument cooling by submergence and direct conduction. This simplified schematic indicates that the passive cooling concept cryogen is most readily resupplied by in-orbit refill, whereas tank replacement would be accomplished only with difficulty since the tank is an integral part of the instrument. On the other hand, the open-loop coolant circulation concept croygen tank can be readily replaced. But this method is limited to cooling in the supercritical region of the cryogen unless fluid conditioning is performed at or near the instrument.

The only method of cooling with superfluid helium without fluid conditioning is by the submergence of surrounded passive cooling concept. This is because, based on current technology and design limitation, superfluid helium cannot be transferred without the development of the passive screen

device that is currently undergoing development. This development with LH_2 will make in-orbit transfer of subcritical fluids other than helium possible and available in the near future.

4.6.3 Cryogen Resupply Techniques

Figure 4.6.3-1 defines the state of the art resupply techniques corresponding to the cryogen states. In each case, the replacement of the cryogen container would be by RMS and/or EVA. The supercritical fluids can be transferred in-orbit by adding energy to the tank (increase in temperature) or by system blow-down. The two phase liquid transfer requires liquid settling by acceleration in order to orient the liquid at the outlet end of the tank. The required acceleration levels and transfer times will be established. The passive expulsion technique is the desirable method since it does not disturb other experiments. The technology is currently being developed and should be available for LH_2 transfer. The resupply of solid cryogen is by direct replacement. The units could be located on the platform arms provided the temperature requirements can be satisfied with the increased transfer distance.

TYPE OF CRYOGEN	TECHNIQUES
SUPERCRITICAL	• REPLACE TANK(S)
	• IN-ORBIT RESUPPLY BY INCREASE IN CRYOGEN BULK TEMPERATURE OR DEPRESSURIZATION (BLOWDOWN)
SATURATED AND SUBCRITICAL	• REPLACE TANK(S)
	• IN-ORBIT RESUPPLY FROM PLATFORM OR ORBITER - LIQUID SETTLING VIA ACCELERATION - PASSIVE EXPULSION*
SOLID	• REPLACE UNIT(S)

*NASA LERC IS CURRENTLY MANAGING CONTRACT TO DEVELOP IN-ORBIT LH_2 TRANSFER EXPERIMENT

Figure 4.6.3-1 Cryogen Resupply Techniques

4.6.4 Cryogen Resupply Interface Trade (See Figure 4.6.4-1)

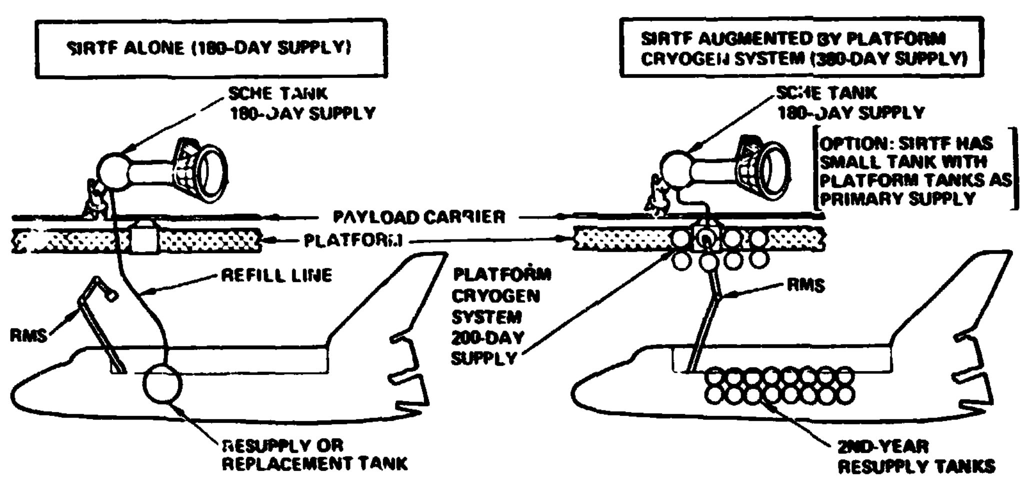
The cryogen resupply options depend on the payload cooling concept. A payload with passive cooling is probably limited to in-orbit resupply from the Orbiter or platform tanks because the payload cryogen tank is usually an integral part of the instrument and its removal and replacement would be an extremely difficult task by EVA. The resupply from the platform tanks is more desirable since it involves shorter lines and could possibly be accomplished by the RMS alone. The open loop coolant circulation concept lends itself to the direct replacement of the payload tank(s) but then the interface is at the payload therefore it could result in temporary interruption of the experiment and would require EVA to preclude damaging the payload. The resupply from the platform modular tank system is the safest and least complicated method. The open loop coolant circulation method lends itself to utilizing the platform tank(s) as the primary supply since it involves only a one-step transfer of the cryogen. Based on current technology, payload instrument cooling with subcritical fluids must be passive and cooling with supercritical fluids or solids can be either passive or open loop.

4.6.5 Supercritical Helium Resupply for SIRTF Free Flyer

Figure 4.6.5-1 illustrates the options for platform-supplied cryogenic tanks for the currently defined SIRTF free flyer. The SIRTF has a 180 day supply of supercritical helium therefore, to extend its life would require resupply every 180 days. The resupply would also require a long line from the Orbiter. With the platform cryogen supply system, the resupply could be accomplished with shorter lines. The platform cryogen supply system could also be used to augment the SIRTF supply to extend its life to 380 days; therefore requiring a resupply mission once a year instead of twice a year. A cost trade is required to establish the more desirable method.

PAYLOAD COOLING OPTIONS	RESUPPLY OPTIONS
• PASSIVE COOLING – CRYOGEN CONTAINER IS INTEGRAL PART OF INSTRUMENT (I.E., IRAS) – THERMALLY VERY EFFICIENT	• RESUPPLY FROM ORBITER – LONG LINE; EVA OR RMS (?) • RESUPPLY FROM PLATFORM – SHORTER LINE; REPLACEABLE TANKS; RMS AND/OR EVA
• OPEN-LOOP COOLANT CIRCULATION – MAJOR CRYOGEN CONTAINER IS EXTERNAL TO INSTRUMENT (I.E., CURRENT SIRTF) – TWO-STEP IN-ORBIT TRANSFER	• REPLACE CRYOGEN TANK(S) DIRECTLY – INTERFACE AT PAYLOAD – TEMPORARY INTERRUPTION OF EXPERIMENT UNLESS ALTERNATIVE SUPPLY IS AVAILABLE • RESUPPLY FROM ORBITER – LONG LINE (≈ 25 M FOR SIRTF) – INTERFACE AT PAYLOAD; EVA OR RMS • RESUPPLY FROM PLATFORM MODULAR TANK SYSTEM – INTERFACE AT PLATFORM (NOT PAYLOAD) – SHORT LINE, SAFER, AUTOCONNECT UMBILICALS
• OPEN-LOOP COOLANT CIRCULATION – MINOR CRYOGEN CONTAINER IS EXTERNAL TO INSTRUMENT BUT PLATFORM TANK(S) PROVIDE PRIMARY SUPPLY – EFFICIENT ONE-STEP IN-ORBIT TRANSFER	• REPLACE PLATFORM TANK(S) – INTERFACE AT PLATFORM (NOT PAYLOAD) – PAYLOAD CARRIES MINOR SUPPLY FOR THERMAL CONTROL PRIOR TO DEPLOYMENT

Figure 4.6.4-1 Cryogen Resupply Interface Trade



RESUPPLY OPTIONS (SEMIANNUAL)

- REPLACE SIRTF SCHE TANK
- IN-ORBIT REFILL DIRECTLY FROM ORBITER

RESUPPLY OPTIONS (ANNUAL)

- REPLACE SIRTF SCHE TANK AND PLATFORM CRYOGEN TANKS
- IN-ORBIT REFILL OF SIRTF SCHE TANK DIRECTLY FROM ORBITER AND REPLACE PLATFORM CRYOGEN TANKS
- IN-ORBIT REFILL OF SIRTF SCHE TANK THROUGH PLATFORM CRYOGEN TANKS AND REPLACE PLATFORM CRYOGEN TANKS

Figure 4.6.5-1 Supercritical Helium Resupply for SIRTF Free Flyer

Another and perhaps more desirable approach for many reasons, is to have the payload self-provide cryogenics on attached pallets. These conceivably could be replaced as shown conceptually in Figures 4.6.5-2, 4.6.5-3, and 4.6.5-4.

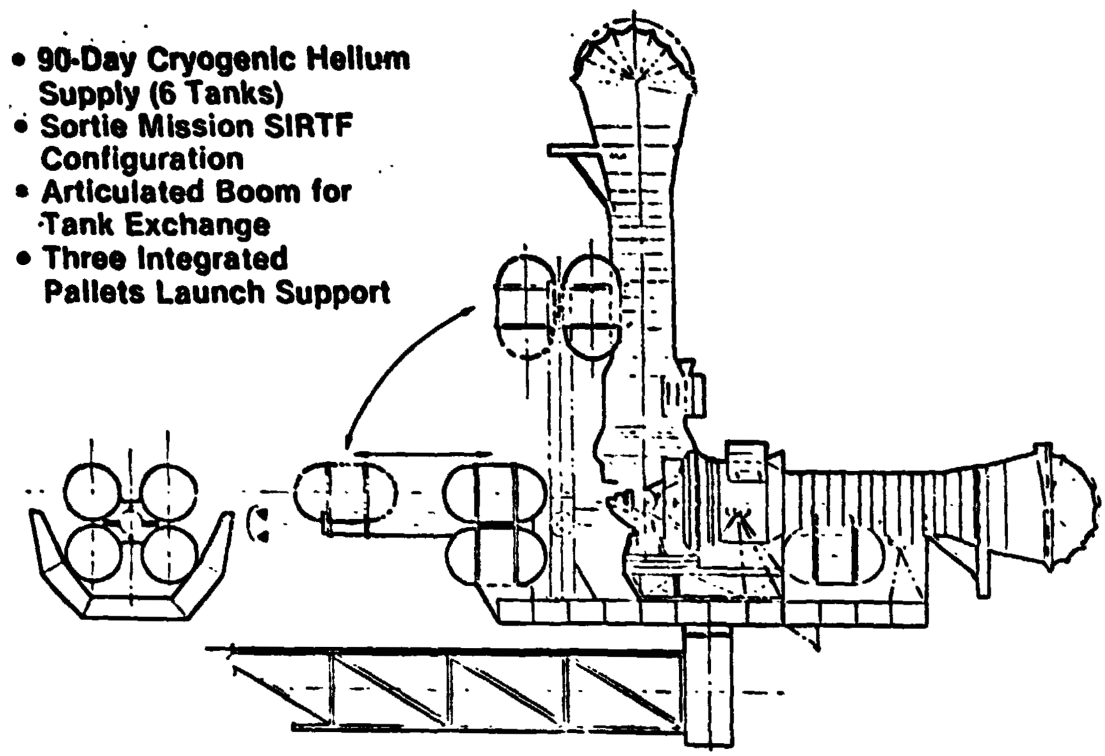


Figure 4.6.5-2 SIRTF Cryogenic Tank Automated Exchange Provisions (A)

- 90-Day Cryogenic Helium Supply (6 Tanks)
- 30 Days Between Exchange Cycles
- Replacement Tanks and Exchange Provisions Mounted on Half Pallet
- Sortie Mission SIRTF Configuration

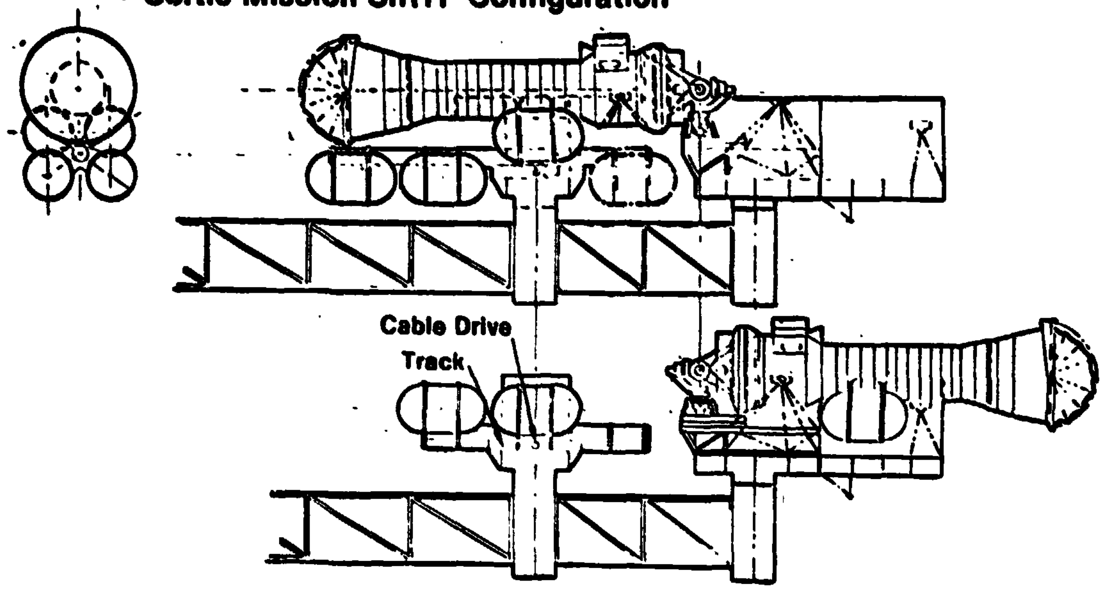
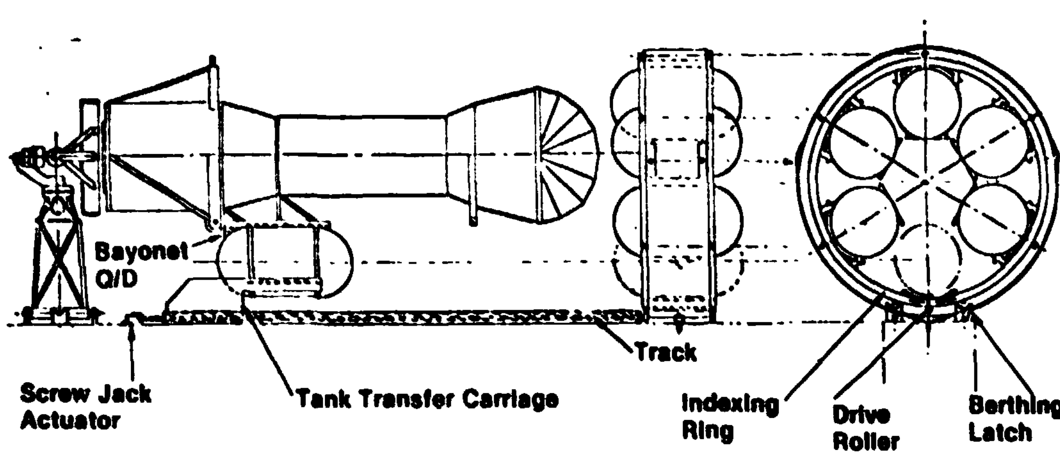


Figure 4.6.5-3 SIRTF Cryogenic Tank Automated Exchange Provisions (B)



- 90-Day Cryogenic Helium Supply
- 15 Days per Tank (Spacelab Size)
- Automated Tank Transfer Provisions Are an Integral Feature of the Platform

Figure 4.6.5-4 SIRTF Cryogenic Tank Transfer Provision

4.6.6 "Common" Platform Mounted Tank Size Trade

The tank size trade is based on the four data points available. HEAO-B and IRAS are related data included to provide additional information. The goals of the trade are to resupply a payload once a year and the tank sized to be transportable in the Orbiter and installable on the platform structure without interference. The optimum size appears to be a 1.5 m tank (1650 liters). As shown in Figure 4.6.6-1, SIRTF will require 16 tanks for resupply but this is probably the upper end of the cryogen requirements. Most of the payloads will require one to three tanks.

OBJECTIVE

- TO DETERMINE OPTIMUM TANK SIZE TO SATISFY MANY USERS

GOALS

- RESUPPLY TWO TO FOUR TIMES A YEAR
- SIZED TO BE: TRANSPORTABLE IN THE ORBITER, MODULARLY APPLICABLE TO MANY USERS, AND INSTALLED ON THE PLATFORM STRUCTURE WITH MINIMAL INTERFERENCE

OPTIONS

- USE SAME TANK AS PAYLOAD
- USE NEW BROAD-USE TANK

ASSUMPTION

- SPHERICAL TANK WITH 150 mm ALLOWED FOR MULTILAYER INSULATION AND VAPOR-COOLED SHIELD

TANK SIZE AND NUMBER TRADE

PAYLOAD	CRYOGEN REQUIRED FOUR TIMES A YEAR (LITERS)	TANK O.D. (m)	NUMBER OF TANKS
AST-1	250 SFHE	0.9	1
		0.8	2
SIRTF (FREE-FLYER)	4930 SCHE	2.3	1
		1.8	2
		1.6	3
		1.5	4
HEAO-B*	750 LHE	1.3	1
		1.0	2
IRAS*	135 SFHE	0.8	1

*RELATED DATA

SELECTED CONCEPT

- ONE LARGE TANK FOR HEAVY USERS
- SEVERAL SMALL TANKS FOR OTHERS
- LARGE TANK WILL PROBABLY BE CYLINDRICAL TO MINIMIZE DIAMETER AND MAXIMIZE USE OF LENGTH ALONG PLATFORM ARM

Figure 4.6.6-1 Tank Size Trade

4.6.7 Tank Replacement vs Tank Refill (See Figure 4.6.7-1)

Resupply by the tank refill method is the desirable method since it is applicable to the passive (with difficulty) and open-loop coolant circulation cooling concepts for any type of cryogen. To transfer LH_e based on available or developing technology requires a settling force (i.e., propulsion force with reboost module or Orbiter). But the relatively long times required for

SELECTED APPROACH	ADVANTAGES	DISADVANTAGES
$\boxed{\text{TANK REPLACEMENT}}$ (FROM SHUTTLE OR PLATFORM MOUNT)	o NO IN ORBIT CRYOGEN TRANSFER o MINIMUM CHILLDOWN LOSSES	o POSSIBLE EVA SUPPORT o DISTURBS EXPERIMENT COOLING o QUICK-DISCONNECT LEAKAGE FOR ENTIRE MISSION (COULD BE CONTAINED AND USED) o PASSIVE COOLING CONCEPT POSSIBLE BUT WITH DIFFICULTY
TANK REFILL (CRYOGEN TRANSFER THROUGH TANKS ATTACHED TO PLATFORM)	o MAXIMUM TOPPING o MINIMAL EVA SUPPORT o INTERFACE AT PLATFORM o POSSIBLE CONTINGENCY RESERVE o QUICK DISCONNECT LEAKAGE ONLY DURING TRANSFER o SUBCRITICAL FLUID TRANSFER WITH PASSIVE SCREEN DEVICE FOR FLUIDS OTHER THAN HELIUM	o TRANSFER SYSTEM REQUIRED o LARGE RESIDUAL FOR SUPERCRITICAL FLUID TRANSFER o SETTLING FORCE REQUIRED FOR SUBCRITICAL HELIUM TRANSFER o CHILLDOWN LOSSES

Figure 4.6.7-1 Tank Replacement vs Tank Refill

transfer line chilldown and fluid transfer is unacceptable from a propellant usage standpoint. NASA LeRC is currently developing a low-g experiment using a passive screen device to transfer LH_2 and this concept should be applicable to all cryogens except helium which probably presents a more severe environment that requires testing and development. The transfer of supercritical fluids either by energy addition or depressurization would result in large residuals and heavy tanks. Therefore, the tank replacement concept is the most feasible method that is applicable to all cryogen types and state.

If the payload requires cooling in the subcritical fluid range for cryogens other than helium, thus requiring the passive cooling concept, then an in-orbit refill using passive screen device to accomplish the transfer can be used.

4.6.8 Tank Refill Analyses (See Figure 4.6.8-1)

The two major issues relating to the tank refill concept for cryogen resupply relates to (1) large residual for supercritical fluid transfer, and (2) time for settling force for subcritical fluid transfer. Therefore, these analyses were done to address these issues.

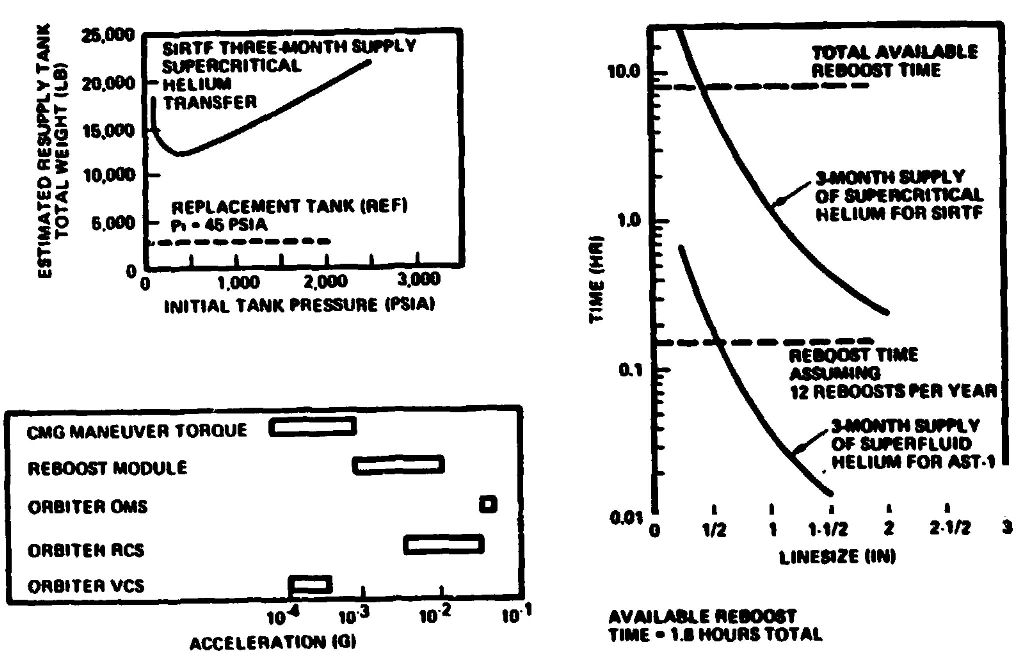


Figure 4.6.8-1 Tank Refill Analyses

Supercritical fluid can be transferred either by (1) energy addition, or (2) depressurization. The energy addition method means that the transferred fluid will be increasing in temperature during the transfer period thus limiting the available temperature regime. The transfer method results in an extremely heavy resupply system (see the figure). Therefore, it is not feasible to refill a tank from a supercritical fluid source.

Subcritical fluid transfer requires a settling force to properly orient the fluid/vapor interface due to the unavailability of a completely passive transfer system. The expected acceleration environment indicates that only the reboost module and Orbiter OMS and RCS can provide the forces required to overcome the random CMG maneuver torque. The total available burn time for the reboost module is approximately 1.8 hours, to be divided over a year. The burn time available from the Orbiter is probably a few seconds. The accompanying chart illustrates the transfer time required as a function of SIRTF and SST-1 transfer line size three-month cryogen requirements. This does not account for the time required for initial settling and chilldown. For a large user like the three-month SIRTF mission, the resupply time is greater than reboost module capability for each reboost for lines as large as two inches. For much smaller users (i.e., AST-1) the transfer time is not as formidable but it is still an undesirable consumption. Furthermore, the resupply tanks must be oriented to utilize the reboost acceleration and the resupply tanks must remain with the Platform until the next resupply mission.

4.6.9 Replacement Tank Location Trade

Figure 4.6.9-1 lists the advantages and disadvantages of the three potential tank locations. Because of the current lack of definition of payload cryogen requirements, design of their tanks and the general difficulty in transferring cryogens in orbit, we conclude that the payloads will be best served by providing payload-mounted or payload pallet-mounted tasks with a reloading approach as shown in Figure 4.6.5-2.

LOCATION (INTERFACE)	ADVANTAGES	DISADVANTAGES
PAYLOAD	• SHORTEST TRANSFER LINE • MINIMUM PARASITIC HEAT LOAD • FULLY INTEGRATED PACKAGE • LEAST DISTURBANCE TO PAYLOAD	• INTERFACE AT PAYLOAD • EVA SUPPORT • SIX-MONTH SIRTF MISSION CANNOT BE ACCOMMODATED (IPS OVERLOAD)
PALLET	• TANK REPLACEMENT BY RMS WITH MINIMAL EVA SUPPORT • MINIMAL DISTURBANCE TO PAYLOAD	• DEDICATED VOLUME ON PALLET • TRANSFER LINE REQUIRES EFFECTIVE INSULATION • CANNOT TRANSFER SUBCRITICAL HELIUM • REQUIRES SMALL SUPPLY FOR GROUND TO ORBIT COOLING
PLATFORM	• TANK REPLACEMENT BY RMS WITH MINIMAL EVA SUPPORT • MINIMAL DISTURBANCE TO PAYLOAD • SUBSTANTIAL AND FLEXIBLE COOLING CAPACITY • MAXIMIZE USE OF PLATFORM SPACE • TRANSFER LINE CAN BE EFFECTIVELY INSULATED	• TRANSFER LINE REQUIRES EFFECTIVE INSULATION • CANNOT TRANSFER SUBCRITICAL HELIUM • REQUIRES SMALL SUPPLY FOR GROUND TO ORBIT COOLING

Figure 4.6.9-1 Replacement Tank Location Trade

4.7 POWER SUBSYSTEM TRADES AND ANALYSIS

Selected areas of the power distribution system were analyzed in detail to support specific trades and to develop background information for use in defining unique interfaces and design approaches.

4.7.1 Requirements Summary

Trades and analyses reported on in this section reflect the following requirements.

- Circuit overcurrent protection.
- Circuit connect/disconnect by remote control (includes deadfacing for mate/demate operations).
- Compatibility of connect/disconnect means with Power System Remote Interface Unit (RIU) signal characteristics.
- Flexibility for bus load assignments.
- Selectable source bus redundancy.
- Accommodation for growth with minimum scar.

- Assured low impedance return path for fault currents.
- Power transfer across hinges and rotating joints with minimum complexity.
- Capability for supplying unusually high peak power demands in an economical manner.

4.7.2 Important Factors and Considerations

Salient points driving the trades and analyses include:

- Distribution system sizing to reflect good balance between capability and complexity.
- Redundancy requirements.
- Power System interface recommendations.
- Payload isolation from potential sources of electrical interference.
- State-of-the-art of specified components.
- Unusual load requirements.

4.7.3 Work Accomplished

Trades were performed to select preferred methods of circuit protection and switching, cross-arm power distribution design, and means for supplying peak/pulse power loads. Analyses reported on include development of requirements for an equipment grounding bus and sizing criteria, and details of trailing cable applications plus references to work done in this area on the Power Extension Package program.

4.7.3.1 Circuit Protection and Switching

All platform primary power circuits (30V or 120V) are provided with overcurrent protection by devices in the positive circuit wire. Figure 4.7.3-1 shows six options which provide the required overcurrent protection. Options A and C utilize a single series fuse. Options B and D add a switchable redundant fuse. Options E and F combine overcurrent protection and circuit switching

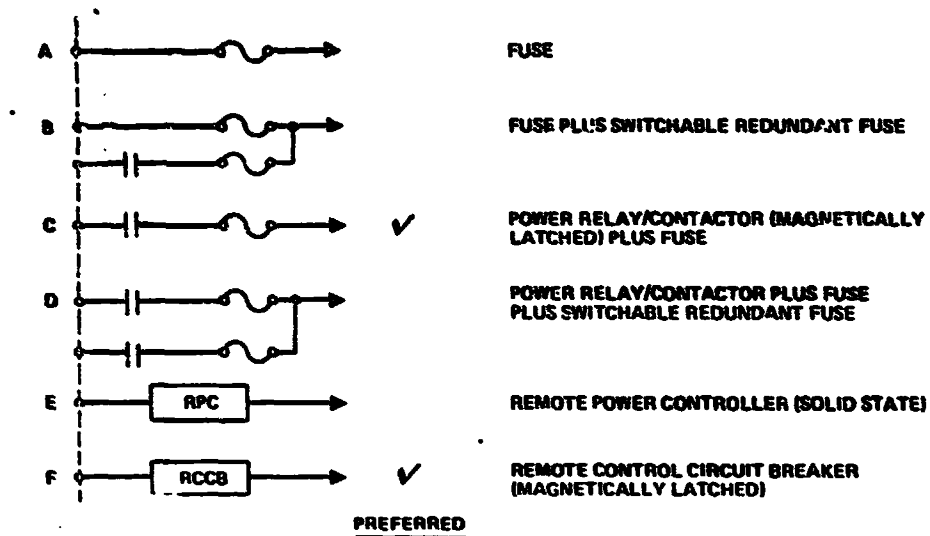


Figure 4.7.3-1 Platform Power Circuit Protection/Switching Options

in a single device. Separate devices (power relay or contactor) are employed for circuit switching in Options C and D. Primary circuit switching is not provided in Options A or B. Since positive remote disconnect capability is required, both of these schemes must be eliminated.

As noted in the figure, Options C and F are the preferred designs. The (remotely controlled) switching device in each case is magnetically latched which eliminates the need for continuous holding power in either the latched or unlatched state. A 28 VDC command pulse of specified duration is required to drive these switches from one state to the other (open to closed; closed to open). The other switching device (E), Remote Power Controller (RPC) is a solid state switch. This device requires multiple low voltage control signals versus the single level 28V commands for the electromechanical switching elements in the preferred types. In addition, there is a minimum leakage current with the solid state RPC, wher , the circuit is physically opened by the contacts in either of the preferred units If numbers of RPC's are

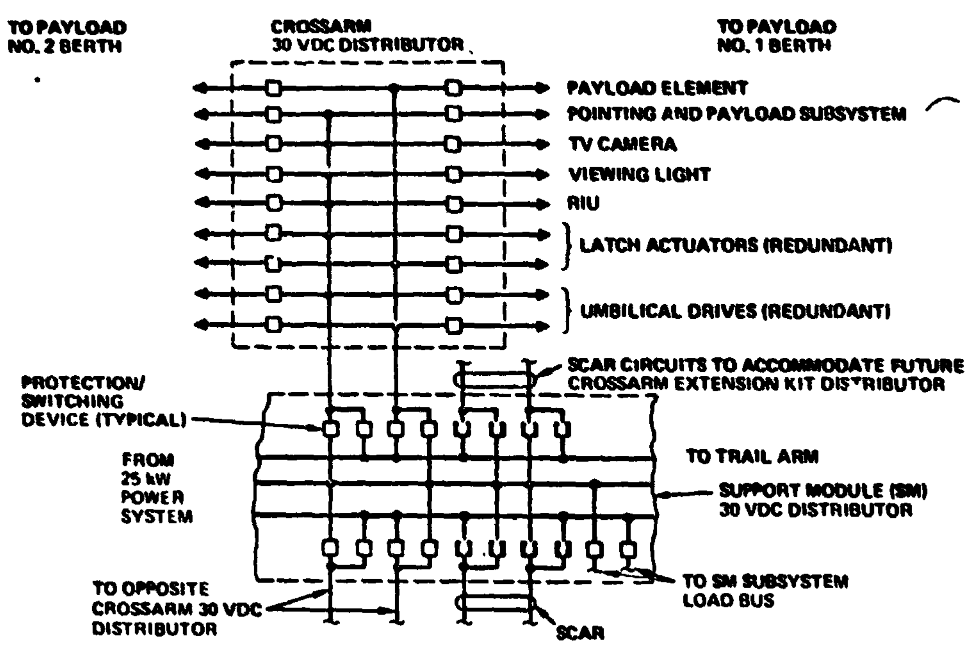
used, it can be difficult to maintain circuit isolation levels within normally specified limits. In the "on" condition, the RPC solid state switch is driven to saturation. The voltage drop across the switch is greater than that across mechanical contacts so an additional loss is incurred over and above the finite control power loss.

In general, RCCB's (F) are preferred over power relays/contactors (C) for non-redundant circuits since they offer reclosure capabilities after tripping. For redundant applications, power relays are more economical. Both types readily accommodate auxiliary contacts which is another advantage over RPC's. In the 25 kW Power System reference concept, Remote Interface Units (RIU) supply all discrete commands. The baseline RIU outputs a +28 volt pulse supplying a maximum of 200 milliamperes for a nominal 6 milliseconds. The 6 millisecond pulse duration is too short to operate most power relays and RCCB's. In some cases, the 200 milliampere output does not provide the required drive. For devices which require less than 200 milliamperes to actuate "pulse stretching" of the 28V discrete command can be employed to provide sufficient duration to latch or unlatch as needed. An alternate approach is to use drivers which latch/unlatch in less than 6 milliseconds to apply 28V control power directly to power relays/RCCB's equipped with throat cutting (self interrupting) actuating coil circuits.

Power relays/contactors suitable for the intended operation are available with high current ratings at 28 VDC. RCCB's are also available although at lower current ratings. Devices rated at 120 VDC for space applications are not generally nor readily available; however, the technology base exists with components used in commercial and industrial power systems. It is recommended that development of the required higher voltage devices be supported as needed to assure timely availability for use in the 25 kW Power System/SASP and related programs.

4.7.3.2 Cross-Arm 30 VDC Power Distribution

The design for distribution of 30V power on the Second Order Platform cross-arms should achieve good balance between isolation of payload circuits from transient sources, switching complexity, wiring complexity, flexibility, and scar penalty to accommodate an extension cross-arm "kit". A scheme which achieves minimum complexity with minimum scar is shown in Figure 4.7.3-2. Scar circuits are indicated by the darkened protection/switching device boxes. The payload element (experiment) circuits to both berthing ports on the cross-arm, share a common feeder. All subsystem circuits also share a common feeder. The merits of this scheme therefore, depend on each of the loads connected to a common bus being relatively insensitive to transients produced by the others.



- MINIMUM SCAR PENALTY FOUR SCAR CIRCUITS
- MINIMUM ISOLATION OF PAYLOAD CIRCUITS
- MINIMUM WIRING ON CROSSARM
- SWITCHABLE BUS REDUNDANCY
- MAXIMUM RATED PROTECTION/ SWITCHING DEVICES/CABLE CIRCUITS

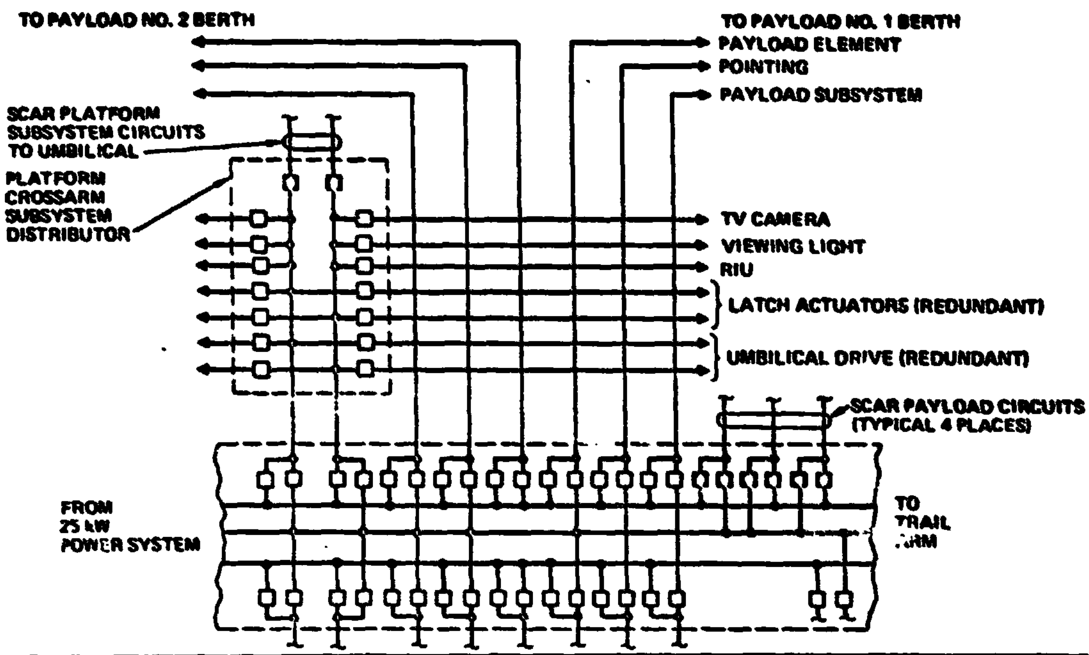
Figure 4.7.3-2 Crossarm 30 VDC Power Distribution Scheme A

Switching provisions in the Support Module (SM) distributor permits selection of either of two source buses for each feeder. However, loss of a single feeder either terminates or curtails experiment activity at both of the cross-arm ports. A common feature to each of the schemes considered in this trade is the use of a redundantly supplied auxiliary bus for the SM subsystem loads. In addition, certain subsystem loads are in themselves, redundant, e.g., actuators, TCS pumps and inverters. As also noted, redundant circuits are provided for platform cross-arm subsystem redundant actuators and drives which are critical for docking/undocking, but are inactive at all other times.

Figure 4.7.3-3 shows a second scheme which is essentially the antithesis of the first. It offers maximum isolation and flexibility for all payload circuits (experiments, pointing, and subsystems), but at the expense of maximum scar penalty and complexity. In this scheme loss of a single feeder affects activities only at the associated payload berth. Expansion to accommodate an extension cross-arm kit is by plugging into the scar payload circuits and scar platform subsystem circuits taken to the interface umbilical at the outboard end of the cross-arm.

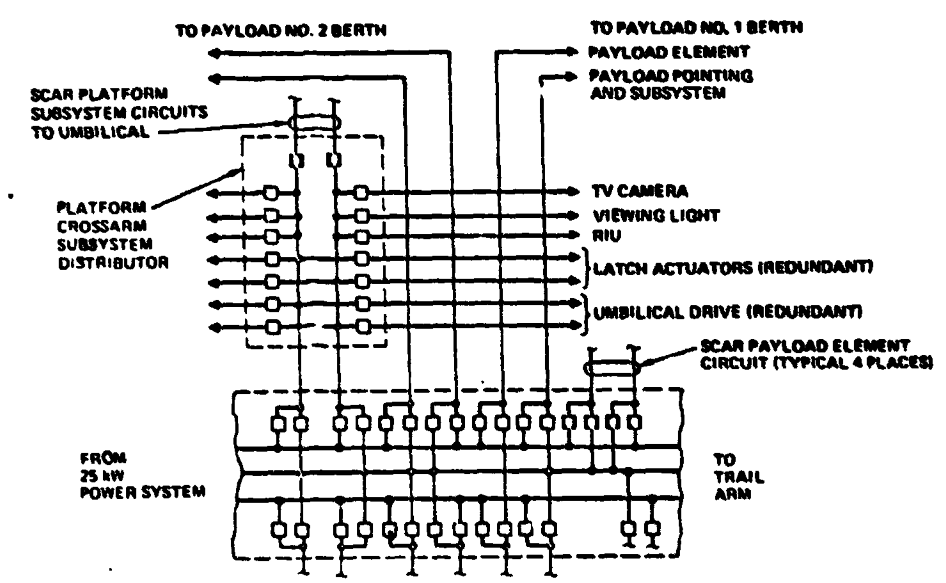
A third scheme which is a simple variation of the second, combines payload pointing and subsystem circuits on a common feeder, but with separate feeders to each payload port, as shown in Figure 4.7.3-4. This system retains full isolation for all payload elements while reducing scar penalty as well as active equipment parts count.

Further simplification is achieved without compromising payload circuit isolation/flexibility by the scheme shown in Figure 4.7.5-5. This is the preferred scheme for cross-arm 30 VDC power distribution. The use of radial feeders to the individual payload elements is retained. A normally open contactor is



- PROVIDES MAXIMUM ISOLATION OF PAYLOAD SYSTEMS
- MAXIMUM SCAR PENALTY
  - 12 SCAR PAYLOAD CIRCUITS
  - 4 SCAR PLATFORM CIRCUITS
- MAXIMUM WIRING ON CROSSARM
- BUS SWITCHING FOR INDIVIDUAL PAYLOAD CIRCUITS ENHANCES FLEXIBILITY
- MAXIMUM NUMBER OF PROTECTION/SWITCHING DEVICES IN SM DISTRIBUTOR

Figure 4.7.3-3 Crossarm 30 VDC Power Distribution Scheme B



- PROVIDES MAXIMUM ISOLATION BETWEEN PAYLOAD ELEMENTS
- PAYLOAD POINTING AND SUBSYSTEM ON COMMON BUS
- BUS SWITCHING FOR PAYLOAD CIRCUITS RETAINED
- SCAR PENALTY
  - 8 SCAR PAYLOAD CIRCUITS
  - 4 SCAR PLATFORM CIRCUITS
- LESS WIRING, FEWER PROTECTION/SWITCHING DEVICES THAN SCHEME B

Figure 4.7.3-4 Crossarm 30 VDC Power Distribution Scheme C

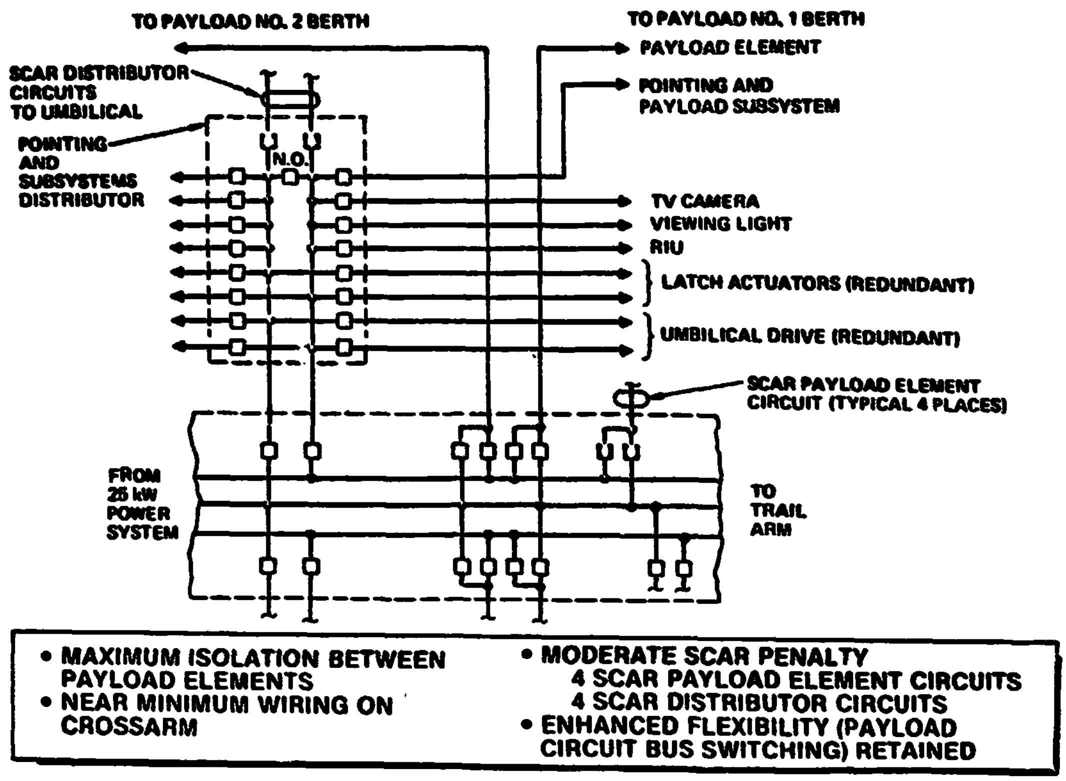


Figure 4.7.3-5 Crossarm 30 VDC Power Distribution Scheme D ✓ Preferred

added between the buses in the pointing and subsystems distributor to permit supplying all distributor loads, as required, for the loss of either feeder from the SM distributor. The contactor and feeder circuits are sized accordingly.

Compared to the first scheme (Figure 4.7.3-2), the advantages of this approach are that it (1) provides maximum isolation between payload elements for both the basic and extended second order platforms, (2) maintains isolation between payload subsystems, (3) offers higher indicated reliability, and (4) offers lower or comparable system cost. The disadvantages are (1) higher scar weight, (2) increased overall cable weight, and (3) increased number of trailing cable installations to cross rotating/hinged joints. The total number of cables may be reduced, however, due to routing payload element

circuits directly to the berthing port umbilicals instead of via cross-arm distributor.

4.7.3.3 Cross-Arm 120 VDC Power Distribution

Power distribution at 120 VDC is provided as a high efficiency alternative to distribution at 30 VDC. It is offered as an option for payload elements only. It is attractive for large bulk power usage (e.g., furnaces) or where a higher degree of isolation is required than can be economically provided at 30 VDC.

To present potential users with the same basic flexibility afforded by the bus switching schemes in the 30 VDC systems just discussed, a third 120V bus is added at the Power System platform interface. The 25 kW Power System reference concept includes three 120V regulators for the baseline two-bus 120V system. The proposed three-bus system would dedicate a regulator to each bus thereby providing for isolated operation where required. Each 120V payload element circuit could be switched to one of two buses in the SM 120V distributor just as the 30V payload circuits are in the SM 30V distributor. A comparison of the two-bus system with the three-bus system is summarized in Figure 4.7.3-6.

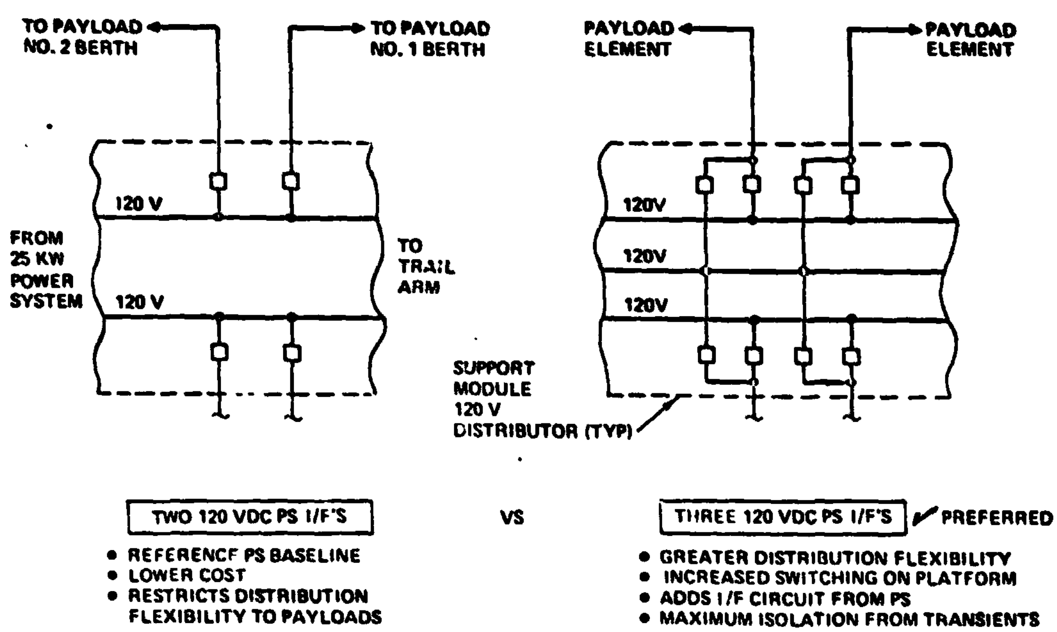


Figure 4.7.3-6 Crossarm 120 VDC Payload Power Distribution

4.7.3.4 Equipment Ground Bus

An equipment ground bus is carried throughout the Platform from the berthing port umbilical to the Power System interface. This provides a controlled low impedance path for equipment primary power fault currents and assures proper operation of fault clearing devices such as fuses and circuit breakers. The required low impedance is normally provided by continuous metallic structure properly bonded at all joints. However, the baseline platform structure uses a composite graphite/epoxy structure for the standoff, cross-arms, mini-arms and trail arm. Only the support module is metal (aluminum). The high resistivity of composite (laminated) graphite/epoxy precludes use of the platform structure as a fault current return path. Therefore, dedicated conductors sized to meet equipment ground bus requirements are provided.

4.7.3.5 Trailing Cables

Superflex wire is employed where trailing cables are used to cross hinges, $\pm 90°$ and $\pm 180°$ rotating joints, and as stowed/deployable cable in extendable platform sections. It will be used wherever significant slack is required and/or wire bend radius must be kept low. The necessary flexibility will be provided by controlling wire stranding and lay (similar to welding cable), and specifying wire insulation/jacketing to achieve required flexure properties compatible with outgassing, abrasion resistance and other constraints. This approach was taken by MDAC for power transfer across articulated joints on the Orbiter Remote Manipulator System (RMS) for the Power Extension Package (PEP) application. Mockup testing to establish feasibility of this concept was conducted by SPAR of Canada, the RMS contractor.

4.7.3.6 Approaches to Supplying Peak/Pulse Power Loads

The platform distribution system will accommodate individual payload element peak power requirements up to ~~6.9~~ Changed to 30 for Final Briefing. kW. Available payload data has indicated relatively few requirements for peak power greater than this level before taking quantum jumps to ~~25~~ 50 kW and higher.

For most applications, Approach A in Figure 4.7.3-7 is adequate. Peak power ~~up to 6.9 kW~~ is supplied directly to the payload element at either 120 VDC (24 kW) or 30 VDC (30 kW). Considerably more power could be supplied for short durations by

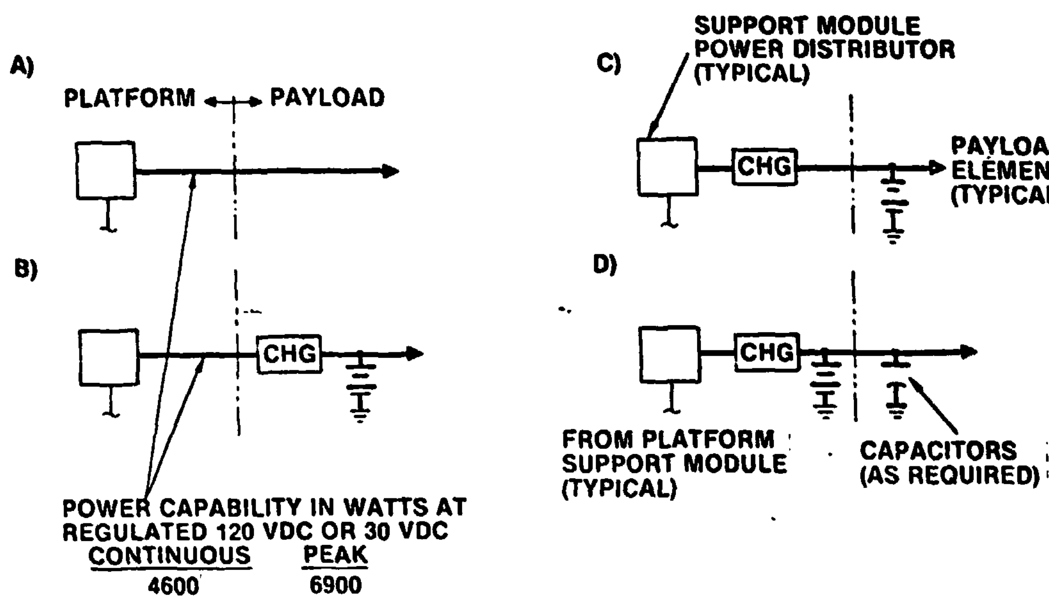


Figure 4.7.3-7 Approaches to Supplying Peak/Pulse Power Loads

making modifications to the Power System and platform systems. The peak power that can be drawn by the loads is constrained by Power System regulator/charger limitations and distribution system capacity even though the Power System array/battery source itself is capable of supplying more power. To take better advantage of the Power System source capability, additional regulators would have to be added together with increased Power System and platform distribution capacity. This would allow the total demand to increase up to

the next limit which is set by the chargers, assuming distribution capacity is increased as required. The peak duration would be limited by array/battery charge/discharge energy balance requirements. As an alternative to adding regulators, options such as bypassing the regulators and/or adding peaking batteries at the load, should be considered.

Bypassing the 120V regulators offers greater increases in peaking capabilities with less penalty than bypassing the 30 V regulators. This approach requires that the load be capable of operating over the wider voltage range set by battery charge/discharge voltage limits, and that the distribution system be capable of handling the increased power flow. The implication of this approach is that it would be best suited for a special single high peak demand user and that a dedicated unregulated bus would be provided uniquely for this application. To avoid significantly impacting both the Power System and platform design for unique peaking applications, peaking batteries can be added at the load as shown by Approach B in Figure 4.7.3-7.

Approach B utilizes platform power capability to charge a peaking battery provided by the payload. This arrangement gives maximum flexibility to the user. It allows scheduling combinations of high peak power - short duration loads, lower peak power - longer duration loads, and/or pulse power loads at user specified voltage levels, limited only be definable platform charging power constraints between battery discharges.

A variation of this arrangement is given by Approach C where the charger is located on the Platform instead of with the load. Approach C can provide the features in B if the charger is user provided or specified, but introduces new interface requirements and possible additional cost for experiment integration.

Approach D on Figure 4.7.3-7 also can provide the features in B, but at the expense of compounding interface control requirements and user integration costs relative to C. In addition, if the load demands pulsed power and the leading edges of the pulses are steeper than the battery can supply, compensating capacitors may be required in the payload. This further complicates the interface by requiring control of the dynamic impedance presented to the payload by the charger, battery, and interconnecting power lines.

The preferred method of supplying peak/pulse power to payload elements demanding more than ~~6.9~~ 24-30 kW is shown in Approach B (Figure 4.7.3-7).

4.7.4 Conclusions and Comments

This section reported on work accomplished in the following areas:

1. Circuit protection and switching
2. Cross-arm 30 VDC power distribution
3. Cross-arm 120 VDC power distribution
4. Equipment ground bus
5. Trailing cables
6. Approaches to supplying peak/pulse power loads

Conclusions reached in each area are summarized below:

- Use (a) latching power relays/contactors in series with fuses, and (b) Remote Control Circuit Breakers (RCCB's).
- Use radial circuits from support module distributors to supply payload elements (experiments) at either/both 30 VDC and 120 VDC. Supply all other payload and cross-arm support equipment circuits from cross-arm 30 VDC distributor.

- Carry an equipment ground bus throughout the Platform to provide the required low impedance return path for fault currents.
- Use superflex wire for trailing cable applications at hinges, joints, and in deployable structure sections.
- Use payload provided peaking batteries for payload element peaks greater than ~~6.9~~ 30 kW at cross-arm berthing ports. At all other ports, provide for peaks up to Power System capability.

4.8 MECHANICAL DESIGN TRADES

Mechanical design trades were performed on the First Order Platform to select a method of berthing the pallets to the Power System.

Trades on the Second Order Platform lead to the selection of designs for arms and support modules. These designs then formed the basis for synthesizing mechanical subsystems which consisted of various arrangements of arm concepts and support modules. A tolerance comparison and a launch configuration trade provided the data for selecting a recommended design.

4.8.1 Requirements Summary

Requirements for the design of mechanical subsystems are summarized in Table 4.8-1.

4.8.2 Important Factors and Considerations

The mechanical subsystem interfaces with nearly all other flights hardware elements including Power System, payloads, Orbiter, and platform subsystems. As such, interface compatibility with these other elements is a prime consideration in the design. From a geometric standpoint, adequate separation of the elements must be maintained with adequate clearance for moving surfaces. This is especially true in the case between the Power System arrays and platform and payload surfaces. Also, clearances between payloads and between

payloads and platform surfaces, must be adequate. Upon Orbiter docking, the design must maintain adequate envelopes for the Orbiter.

- Provide berthing and adequate separation between payloads and payloads and Power System.
- Accessibility for on-orbit servicing and maintenance.
- Provide routing for services between Orbiter, Power System and payloads.
- Capability to be packaged in Orbiter bay for launch.
- Enable payloads to be berthed from Orbiter.
- Minimize on-orbit assembly.
- Minimize weight and cost.
- Accommodate platform subsystem hardware.
- Provide ±180° rotation capability for cross-arm.
- Provide continuous rotation of trail arm.
- Flexibility to accommodate all candidate configurations.
- Payload orientation tolerance between payload and Power System should be minimized.
- Radiator area must be provided on non-deployed platform arm.

Table 4.8.1-1 Requirements Summary

Orbiter compatibility is a prime consideration regarding bay envelope and environment. The launch package must fit within the allowable geometry and must withstand the bay environment. Once on-orbit, the deployment operation requirements must be within RMS operational limits.

4.8.3 Work Accomplished

A brief description of mechanical design trades is given below.

4.8.3.1 First Order Platform Payload Berth

Two basic approaches were considered for supporting payload pallets on the First Order Platform. The simplist method modifies the pallet by installing attachment hardware so the pallet can be berthed directly to the Power System. This approach, shown as Concepts A and B in Figure 4.8.3-1, is low-cost but can use up Orbiter bay volume and is limited in viewing capability.

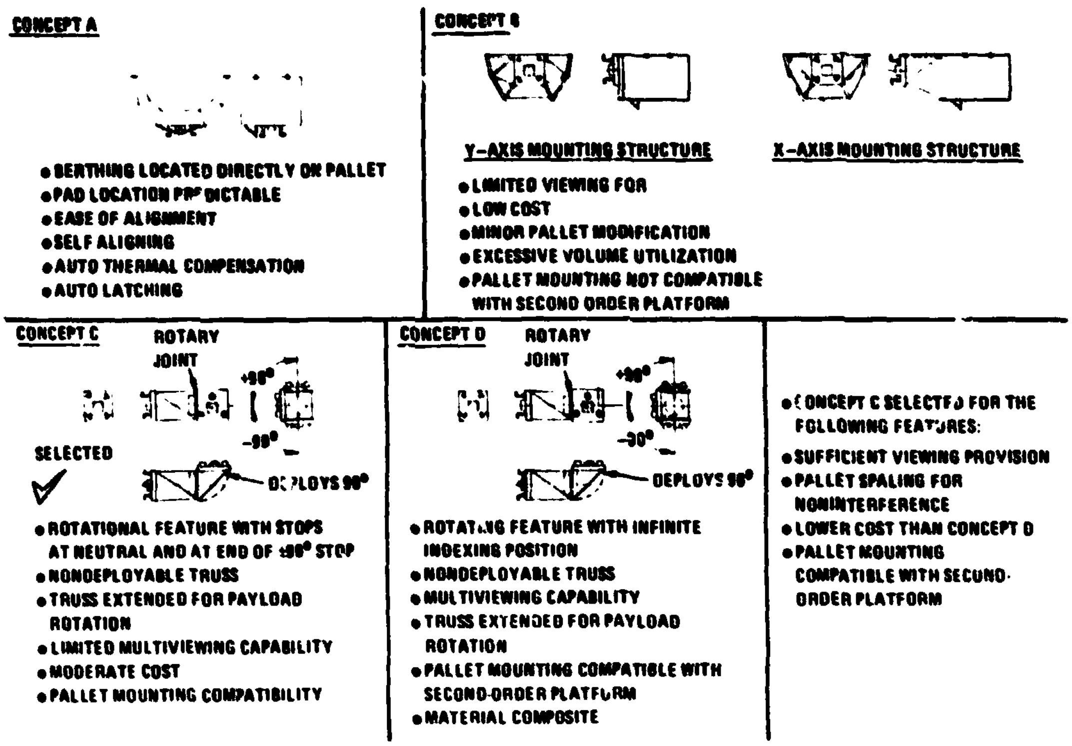


Figure 4.8.3-1 First-Order Platform Pallet Support Concepts

The second approach to pallet mounting provides a simple berth arm which is permanently attached to the Power System, see concepts C and D in Figure 4.8.3-1. Pallets with bottom-mounting provisions are mounted on the berth arm which can be indexed to give flexible viewing capability.

Figure 4.8.3-2 shows a wide range of options for the berth arm which vary in complexity, specifically, indexing position design and degree of remote automation. Concept 4 was chosen because a high degree of automated indexing is obtained with a small increase in cost.

The selected approach has three identical structural configuration arms except for the rotational features. The +X and -Y rotates clockwise and the +Y arm rotates counter clockwise looking outboard from the Power System.

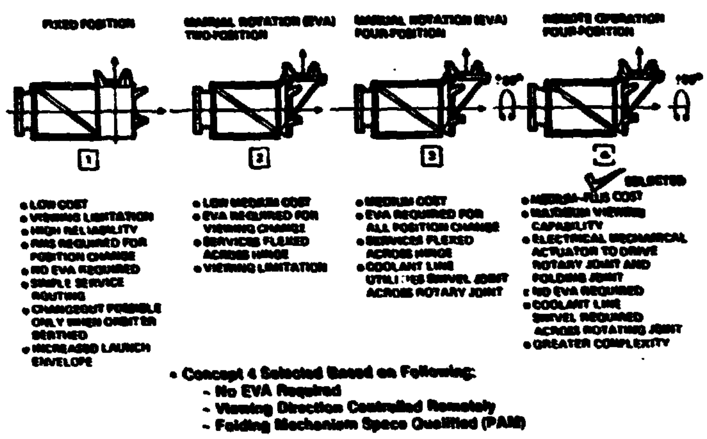


Figure 4.8.3-2 First-Order Platform Payload Berth

4.8.3.2 First Order Platform Pallet Support Concepts

Several alternates were considered for mounting of payload pallets to the Power System docking ports. These alternates plus pros and cons are shown in Figure 4.8.3-3. Bottom mounting of the pallets is recommended to maintain continuity from first order to second order platform design, to avoid loss of payload bay usable length and to minimize dead-ended hardware development.

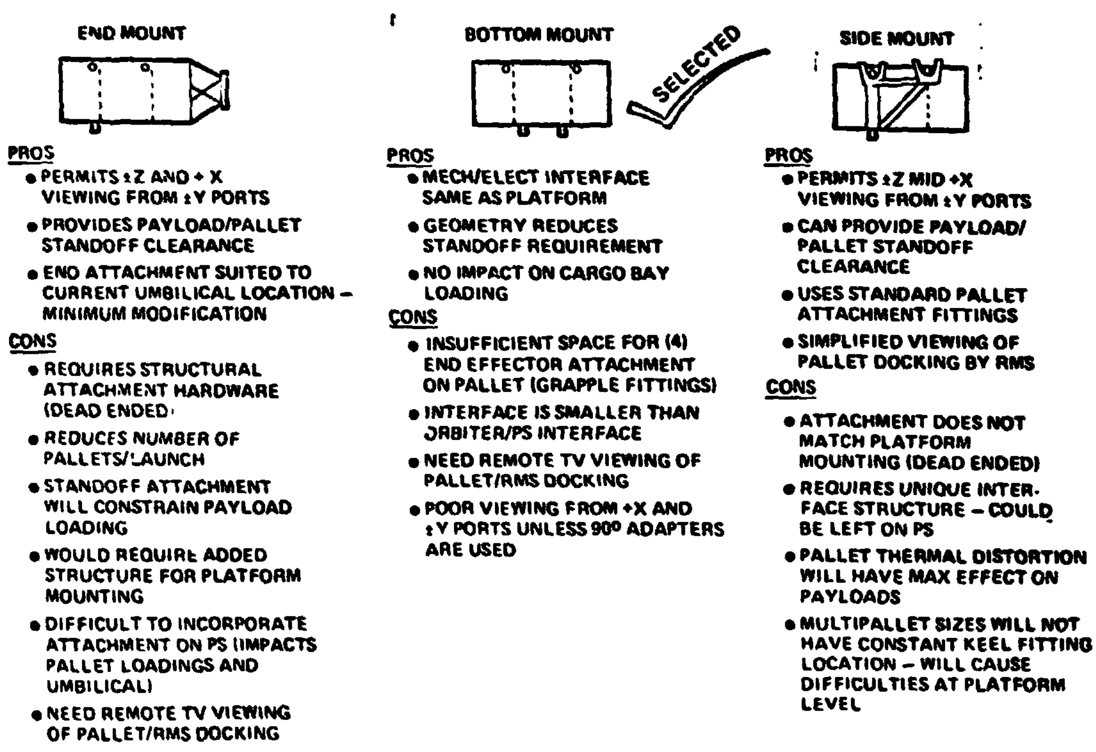


Figure 4.8.3-3 Pallet Docking Options First Order Platform

4.8.3.3 Second Order Platform Arm Design

This trade compared various platform deployable arm design concepts, shown in Figure 4.8.3-4 from a mechanisms standpoint. The concepts were compared based on complexity, packaging efficiency, rigidity and reliability. Results of this comparison are shown in Figure 4.8.3-5. This preliminary study indicates that the folding arm and the expandable truss concept best satisfies these conditions. The best feature of each configuration will be considered in the final structural configuration.

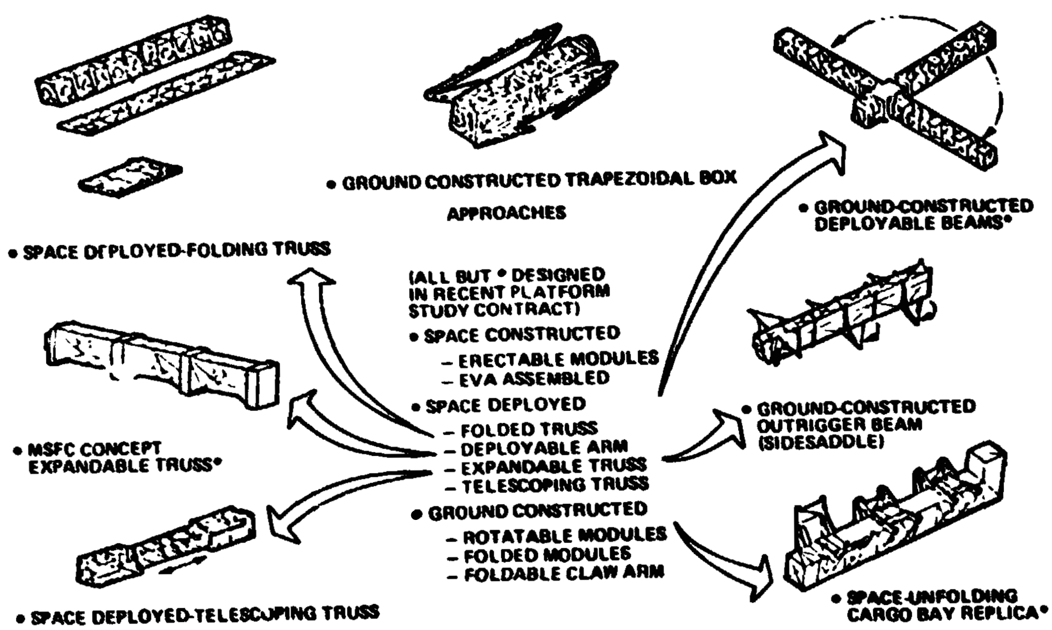


Figure 4.8.3-4 MDAC Structural Buildup Concepts
Plus MSFC's = Broad Starting Base

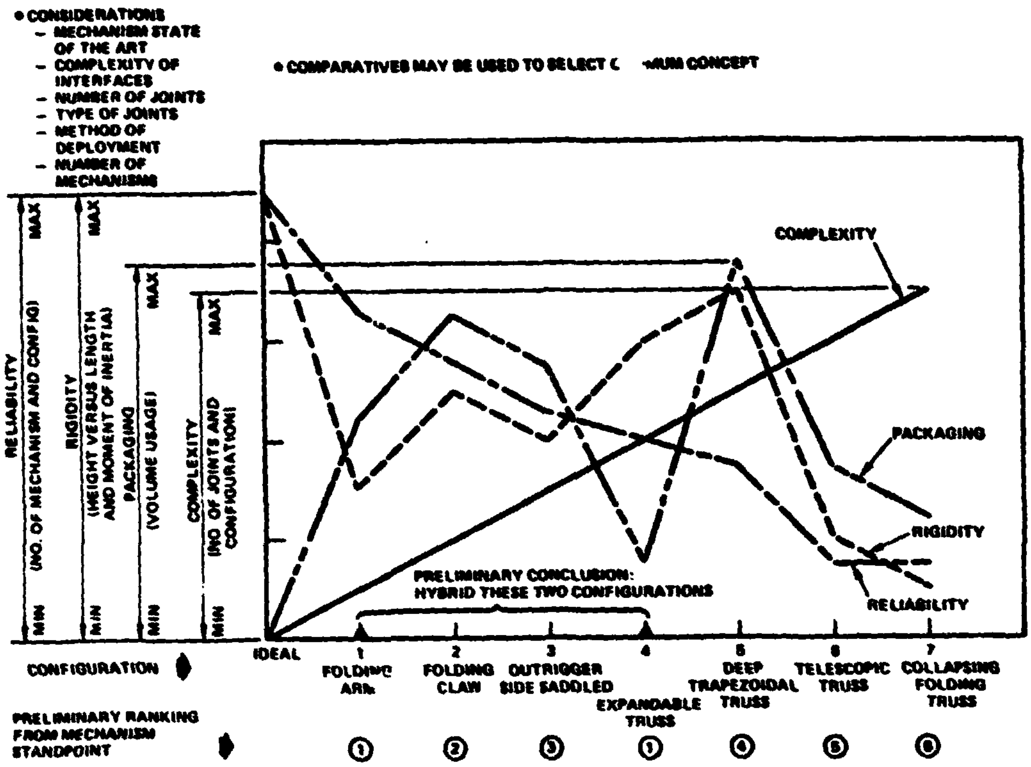


Figure 4.8.3-5 Preliminary Estimates of Mechanism Complexity, Reliability, Rigidity and Packaging

A trade study was performed on the various concepts for compaction ratio. (See Figure 4.8.3-6.) The MDAC telefold expandable compaction ratio of 9.5:1 was the most compact for stowage and was a very promising concept based on high compaction ratio, ease of line routing, minimal thermal distortion, limited number of joints, and low weight.

The basic module is comprised of two berthing ports approximately 20 ft on center; each concept was reviewed for its compaction characteristics. The maximum compaction ratio of 9.5:1 was accomplished with the MDAC telefold expandable concept, each concept has its unique features. The ideal concept will be expandable arm type with a structural configuration that will meet rigidity, reliability, and thermal distortion requirements. Based on these requirements, the MDAC telefold and screw expandable concept is the emerging concept.

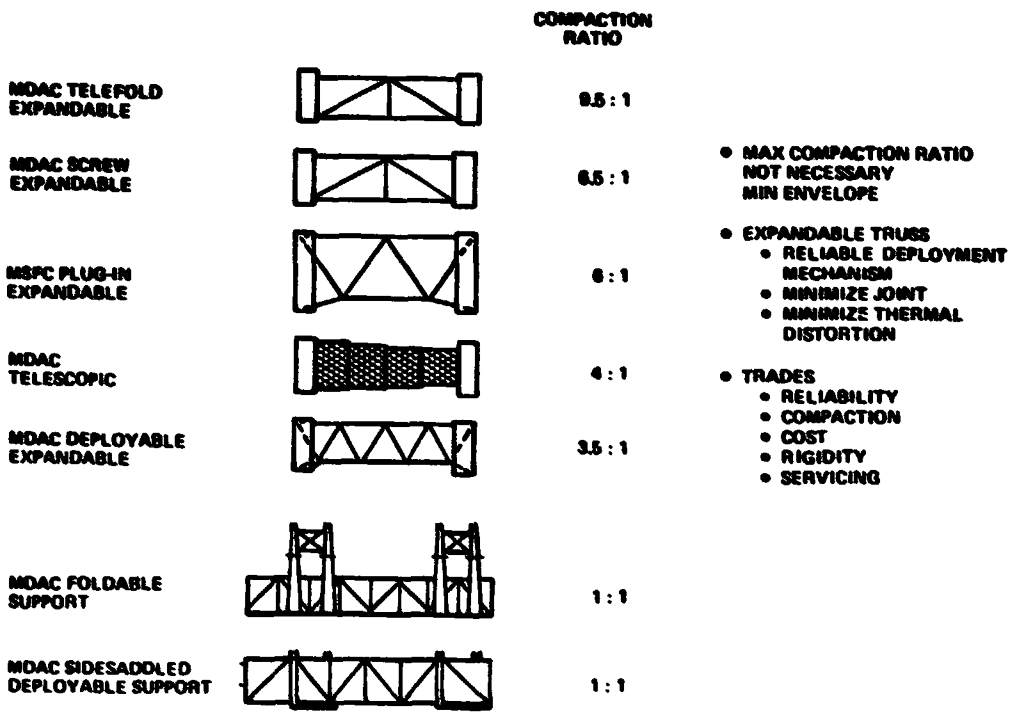


Figure 4.8.3-6 Platform Arm Compaction Comparison

The first quarterly study showed various arm concepts as shown in Figure 4.8.3-7. These concepts were reviewed and narrowed down to three; fixed, telefold expandable, and sector drive expandable. Cost, reliability, serviceability, compaction, and stiffness were the criteria used to compare concepts.

The all fixed truss concept was not selected due to greater dynamic deflection because of a smaller moment of inertia for a design which was compatible with the launch envelope. The fixed truss also had a shorter distance between the payloads. The sector drive was not selected due to higher cost, weight complexity, lower reliability, and greater free play.

The selection criteria shown in Figure 4.8.3-5 indicated that the combination of a fixed and the telefold expandable was very desirable. Figure 4.8.3-8 illustrates this approach.

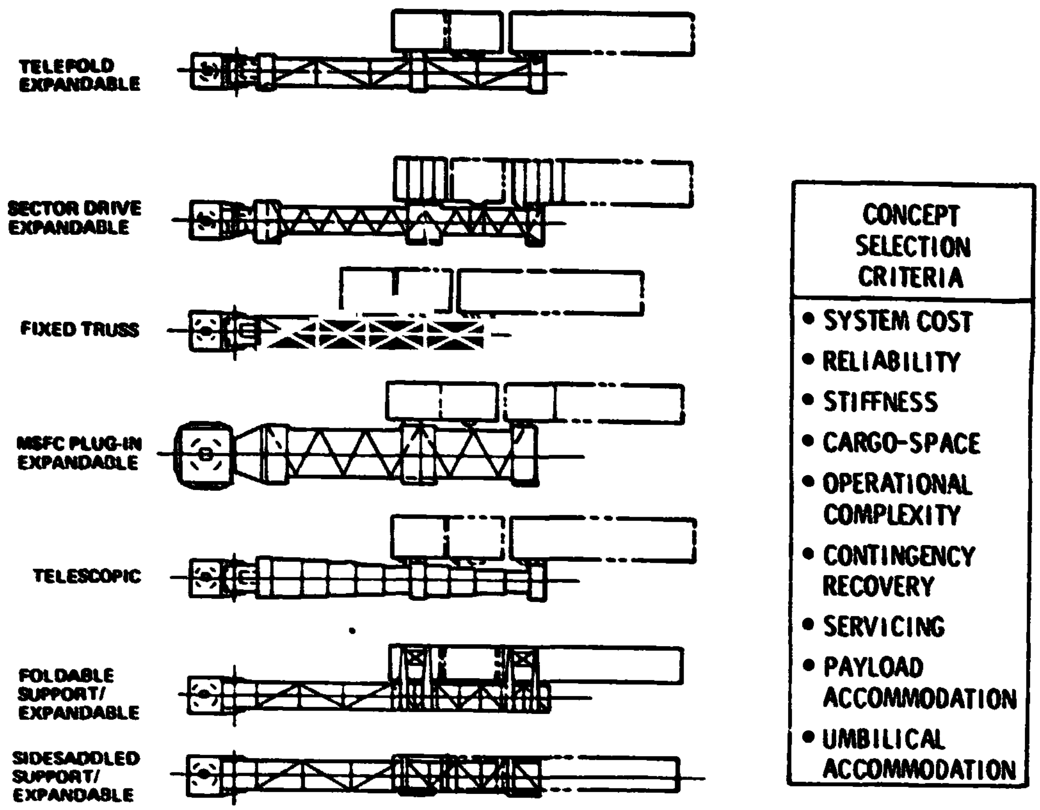


Figure 4.8.3-7 Platform Arm Concept Candidate

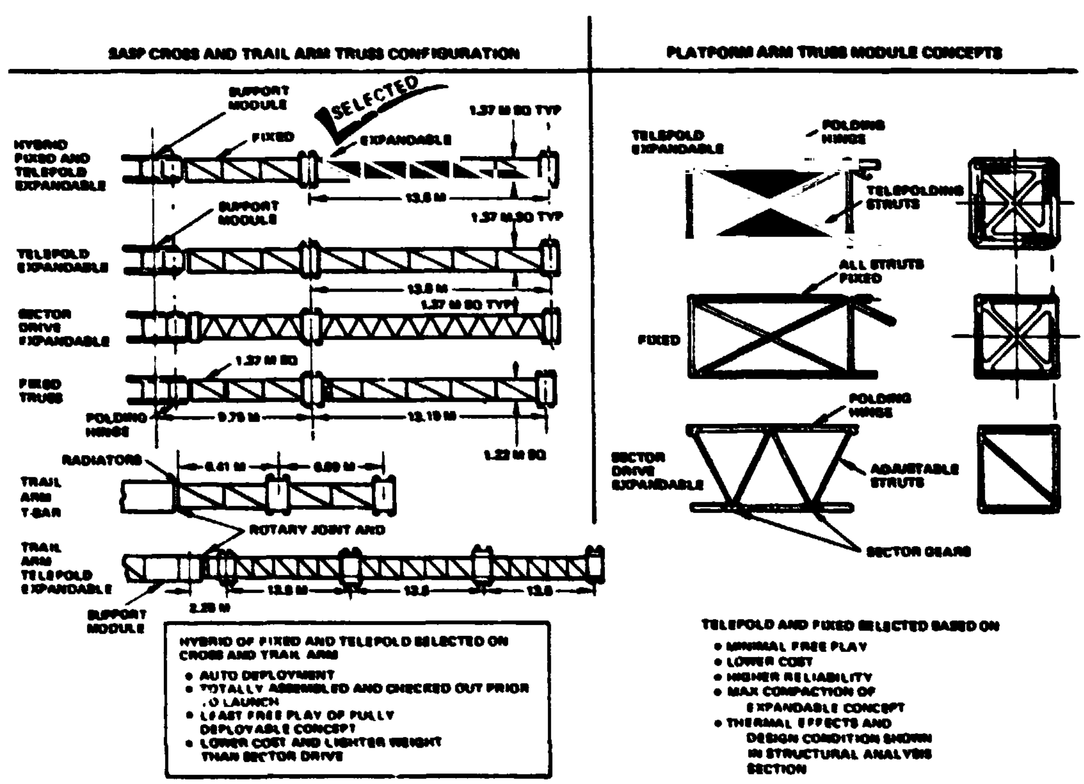


Figure 4.8.3-8 2nd Order SASP Structural Configuration

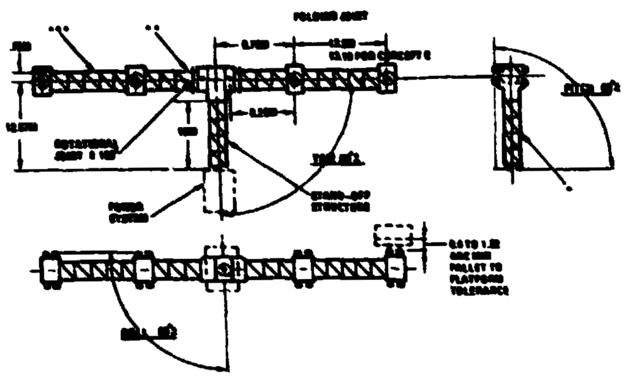
The application of fixed and expandable elements depends on the configuration. For the cross-arm configuration, fixed truss was selected for standoff and inner truss on cross-arm and telefold expandable is used for outer truss on the cross-arms. For T-bar trail arm configuration, the cross-arm, standoff, and support module are identical to the cross-arm concept. The trail arm on this configuration is fixed and the outer truss is telefold expandable. The trail arm configuration uses the same support module as the T-bar trail arm configuration except the cross-arms are deleted and the trail arm consists of fixed truss (radiators mounted) and telefold expandable truss for the outer two trusses.

4.8.3.4 Second Order Platform Tolerance Study

A tolerance study was performed to determine variations that can occur between the Power System and pallet interface due to platform effects of free play, manufacturing and assembly, thermal distortion and rotational indexing. Various combinations of fixed and expandable truss concepts were analyzed for the cross-arm configuration as shown in Figure 4.8.3-9. Table 4.8.3-1 gives the criteria and assumptions used in the study.

In reviewing the compiled results, it is evident that the total error in yaw and roll falls within 3 to 6 arc min. The pitch error is high, but this was due to selecting 12 arc min. on the pointing error. This error can be reduced much lower if the experiments without IPS has lower error requirements, but this will increase the cost of the rotational system.

Results showed that for the various combinations of fixed and expandable truss concepts, the error is relatively small. Concept "E" had the smallest overall tolerance but did not meet the spacing criteria due to compaction requirements for launch. The total SASP accuracies will be summarized in the Attitude Control section.



Concept	Truss Configuration			Wt Lbs
	*	**	***	
A	Telefold Exp	Fixed	Telefold Exp	8,300
B	Fixed	Fixed	Telefold Exp	8,200
C	Telefold Exp	Telefold Exp	Telefold Exp	8,600
D	Fixed	Sector Drive Exp	Sector Drive Exp	9,600
E	Fixed	Fixed	Fixed	7,900

SELECTED

	Tolerances RSS • Arc Minute														
	Concept A			Concept B			Concept C			Concept D			Concept E		
	Yaw	Pitch	Roll	Yaw	Pitch	Roll	Yaw	Pitch	Roll	Yaw	Pitch	Roll	Yaw	Pitch	Roll
Free Play	1.58	1.65	1.65	1.33	1.38	1.38	1.86	1.88	1.89	3.75	2.99	1.58	0.6	0.6	0.45
Mfg & Assy	2.45	2.11	2.27	2.25	2.15	2	2.79	2.48	2.39	0.68	0.84	0.75	1.73	2.03	1.58
Thermal	0.79	0.61	1.11	0.79	0.61	1.11	0.79	0.61	1.11	0.79	0.69	1.11	0.79	0.61	1.11
Rotational Indexing	—	12	—	—	12	—	—	12	—	—	12	—	—	12	—
	4.82	16.37	5.03	4.37	16.14	4.49	5.44	16.97	5.39	5.22	16.52	3.44	3.12	15.24	3.14

- Tolerance Study Performanced on Concepts A - E
- Analysis Reveals Tolerance Relatively Small Between All Concepts
- These Errors Will be Totaled to the Dynamic and Pallet Errors in the Attitude Control Section

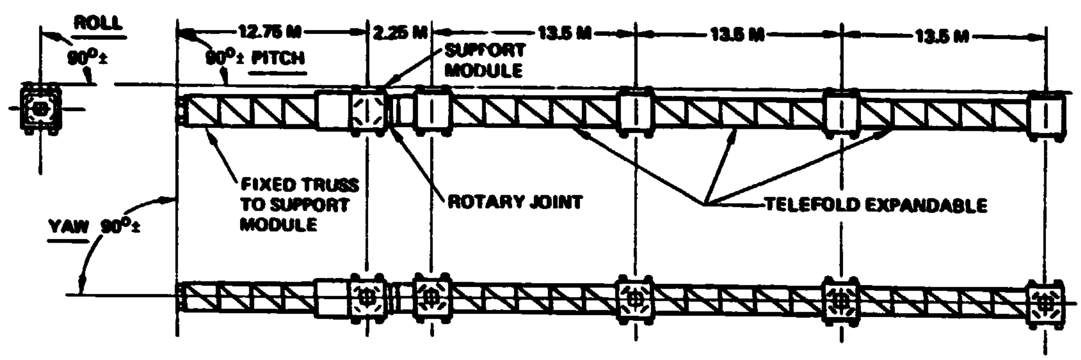
Figure 4.8.3-9 2nd Order SASP Cross Arm Configuration Tolerance Study

CRITERIA & ASSUMPTIONS

- **Structural Configuration Foldable for Launch in (14.5 FT Dia X 44 Ft Lg)**
- **All Fixed Structure SASP to be Foldable and Assemblable by RMS & Packaged in (1) Launch**
- **Structure Matl**
  - **— Graphite Epoxy Composite**
- **Thermal Conditions (Vehicle Attitude (X-POP: Y—PSL)**
- **Pinned Joint Clearances 0.002 In. Max. (For folding and Deployable Structure)**
- **Rss all Tolerances**
- **Controlled Assy & Mfg Tolerances for Ease of Fab**
- **Rotational Joint ± 180°**

Table 4.8.3-1 SASP Cross Arm Configuration Tolerance Study

Figure 4.3.8-10 shows the tolerance study results for the second order trail arm concept. This configuration was also analyzed for mechanical error caused by manufacturing and free play. These errors are similar to the cross-arm configuration and are not a significant contributor to the overall accuracy.



	TOLERANCE RSS ± MIN			VEHICLE WT LB
	YAW	PITCH	ROLL	
FREE PLAY	1.58	1.60	1.60	8400
MFG AND ASSY FREE PLAY	2.38	2.38	1.80	
ROTATIONAL INDEXING	–	–	12	

- FIXED AND TELEFOLD EXPANDABLE HYBRID STRUCTURE
- FIXED TRUSS FWD OF SUPPORT MODULE FOR RADIATORS
- EXPANDABLE SECTION BERTH IN ORBIT WITH RMS

Figure 4.8.3-10 2nd Order SASP Trailing Arm Concept
Free Play & Tolerance Study

4.8.3.5 Arm Truss Launch Packaging

Figures 4.8.3-11, 4.8.3-12, and 4.8.3-13 show various options for storage of the SASP. The basic concept shown in Figure 4.8.3-13 of stowing three trusses in line was selected based on deployment reliability, simplicity of the deployment mechanism, and no assembly requirement on orbit.

4.8.3.6 Second Order Expandable Structure Service Routing Concepts

Figure 4.8.3-14 shows various concepts of routing coolant lines and electrical cabling through and expandable structure.

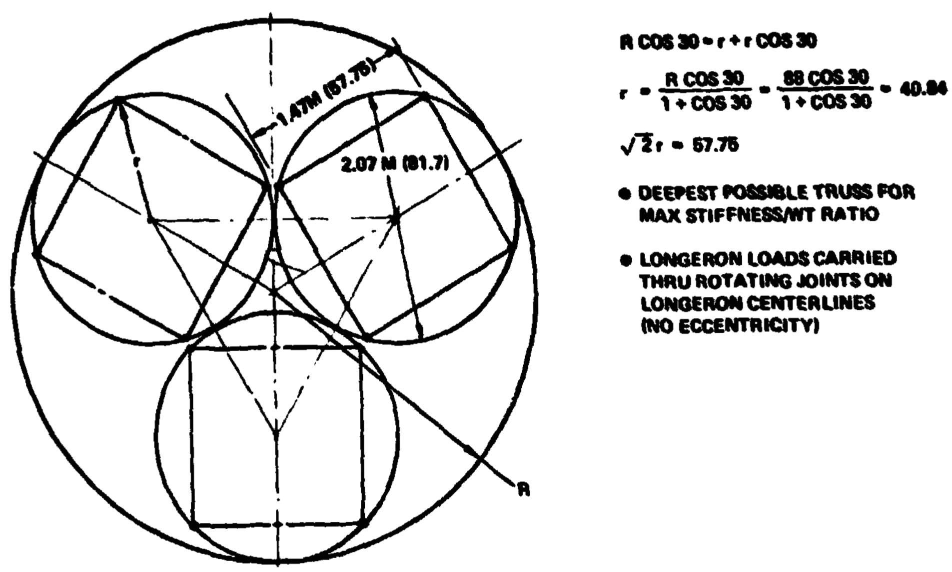


Figure 4.8.3-11 Launch Packaging Concept

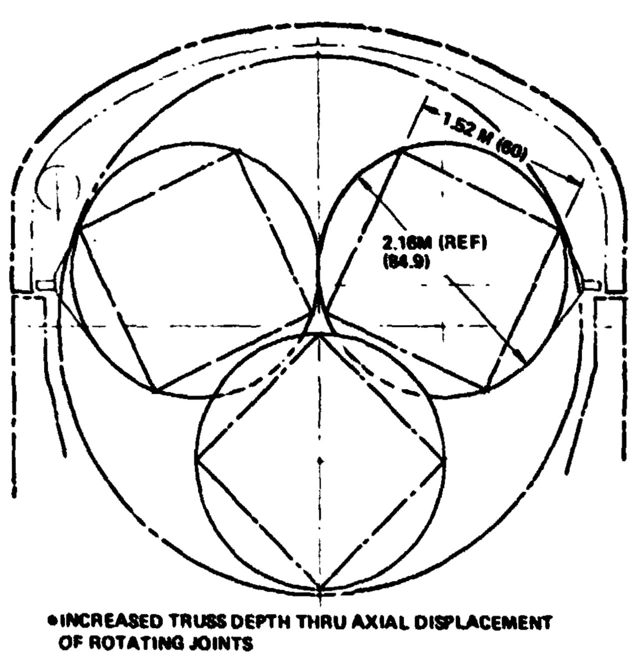


Figure 4.8.3-12 Alternate Launch Packaging Concept

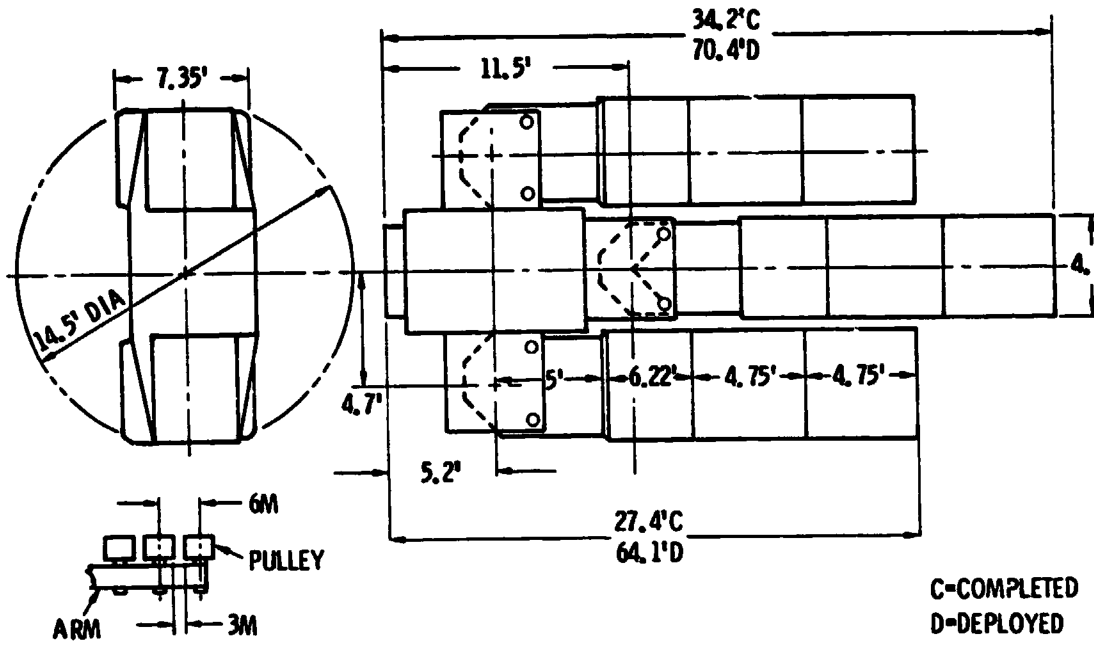


Figure 4.8.3-13 Deployable Arm Expandable Truss
6m Pallet Spacing 3,6, and 9 Pallet Configuration

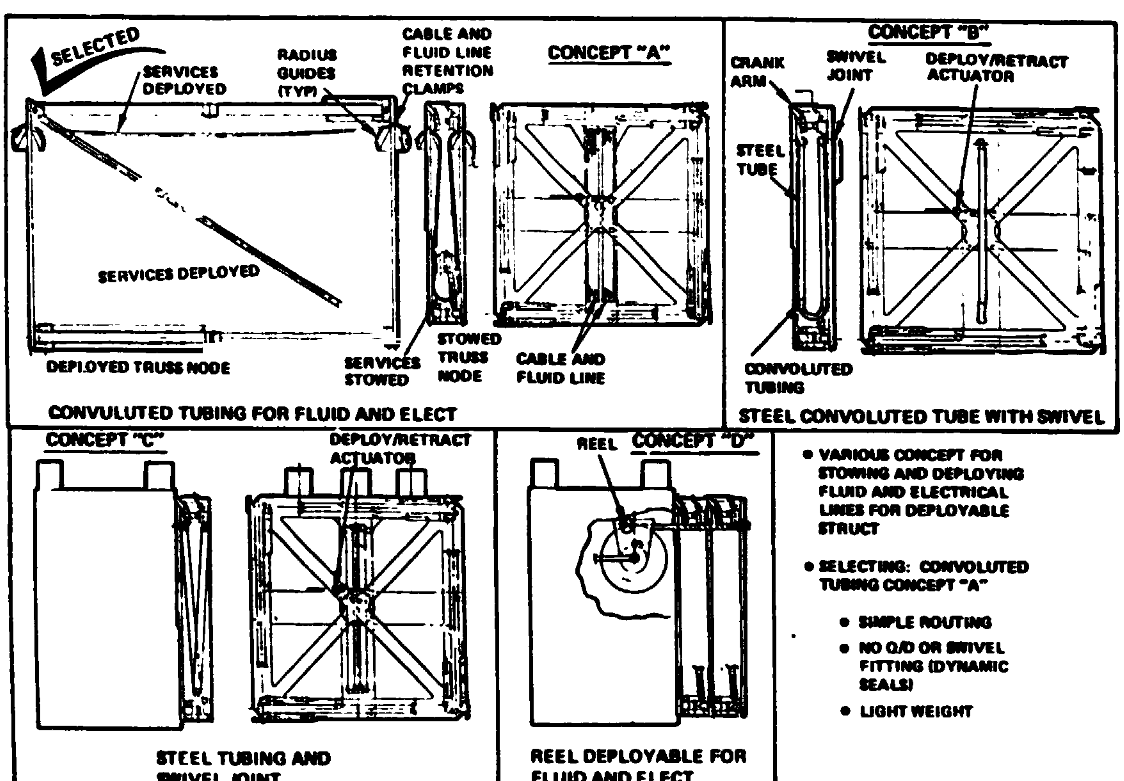


Figure 4.8.3-14 2nd Order Expandable Structure
Service Routing Concepts

There are many problems related to routing lines through deployable structures. Various concepts were studied for their advantages and disadvantages. Concept "A" will only have connections at each berthing port and the lines and tubing will be looped and restrained in the stowed position. When the truss is deployed, the lines will be automatically deployed and will have free play to account for manufacturing tolerances, thermal expansion, and contractions. The advantage of the convoluted tubing is that it is continuous and requires no swivel joint.

Concept "B" utilizes two swivel joints, twc sections of steel tubing, and one section of convoluted tubing for flexing between each expandable node (approximately 8 feet expanded). The electricals are routed in the similar manner except will require two connectors/node.

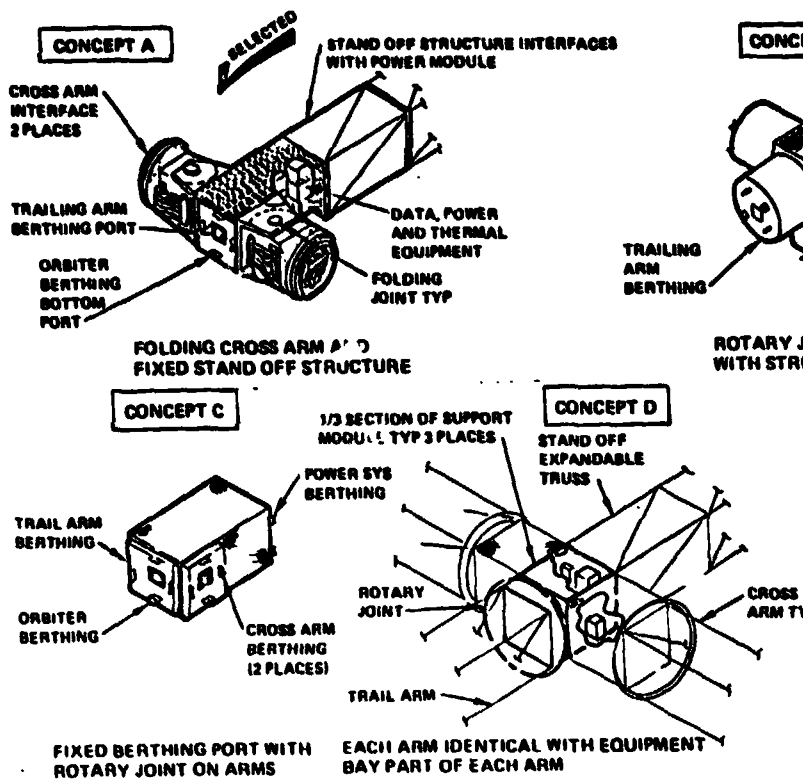
Concept "C" requires three swivel joints and two steel tubes between each node. Electrical cables can be the flat flexible type folded between each node.

Concept "D" is a reel type for the electrical and fluid lines. The expandable structure will deploy the services. Concept "A" was selected based on minimum connections, minimum leak joints, maximum reliability, and lightweight.

Further study should be accomplished in this area, especially since the deployable structure designs differ widely for various configurations, which affects the routing.

4.8.3.7 Support Module Concept Trades

The Support Module is the central system of the unmanned platform which houses the electronics, thermal control and avionics. Various concepts of the support module were studied. (See Figure 4.8.3-15.)



- VARIOUS CONCEPT OF SUPPORT MODULE REVIEWED
- CONCEPT "A" SELECTED BASED ON:
  - NO ASSY IN ORBIT IN THE CROSS ARM CONFIGURATION
  - FULLY AUTO DEPLOYABLE
  - FOLDING CONCEPT FOR LOADING AID AND STORAGE
  - STAND OFF INTEGRAL WITH EQUIPMENT BAY
  - COMPLETE CHECKOUT ON GROUND

Figure 4.8.3-15 Support Module Concept Trades

Concept "A" has a fixed truss standoff between the Power System and support module. This concept has the two cross-arm folding concepts and also has a port for the trailing arm concept. This concept is universal and can be used for the cross-arm or the trail arm configuration. The standoff is required for maintaining the radial clearance between the solar array and the experiment on the cross-arms for the selected payloads.

Concept "B" is attached directly to the Power System without any standoff. The arms have to be assembled in orbit. The rotation feature is integral with the main structure.

Concept "C" is also attached directly to the Power System. The rotational and folding features are located in the cross-arms.

Concept "D" has the equipment bay integral with each arm and when the arms are assembled in orbit, the equipment bay will be one unit.

Concept "A" was selected so that the cross-arm configuration would require no assembly in orbit. This concept is fully auto-deployable in orbit and is totally checked out and assembled on the ground. The folding feature is used for folding the cross-arms for launch compaction and is also used to rotate arms in certain applications for loading and unloading payloads.

4.8.3.8 Payload Pallet Berthing Port Interface Trades

Various methods to interface the pallet to the SASP were studied, see Figures 4.8.3-16 and 4.8.3-17.

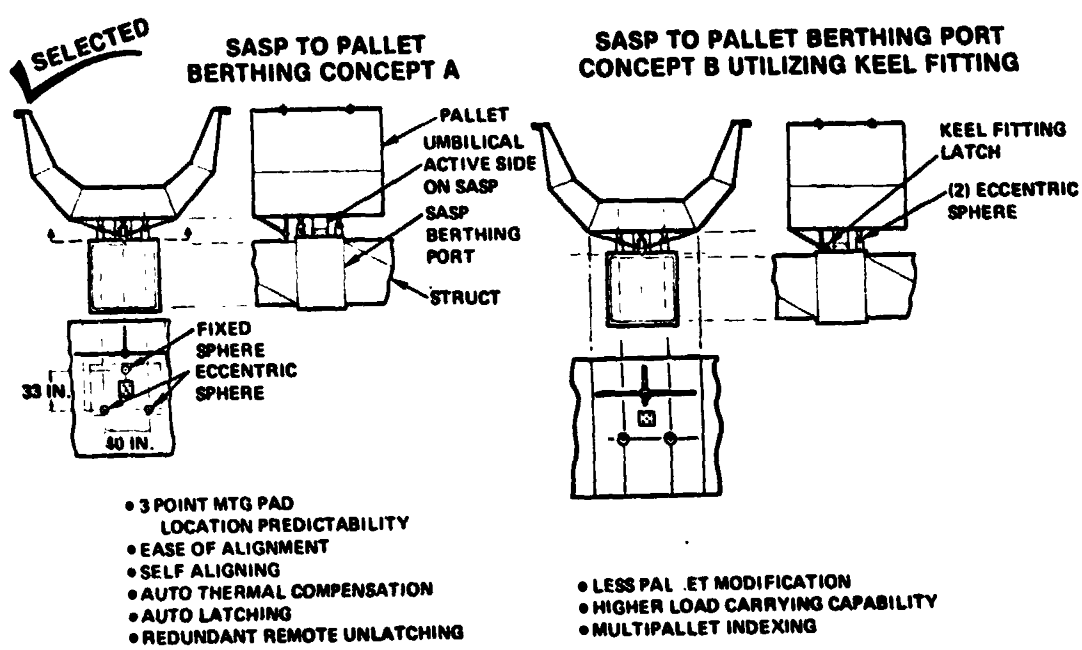


Figure 4.8.3-16 SASP to Pallet Berthing Interface Concepts

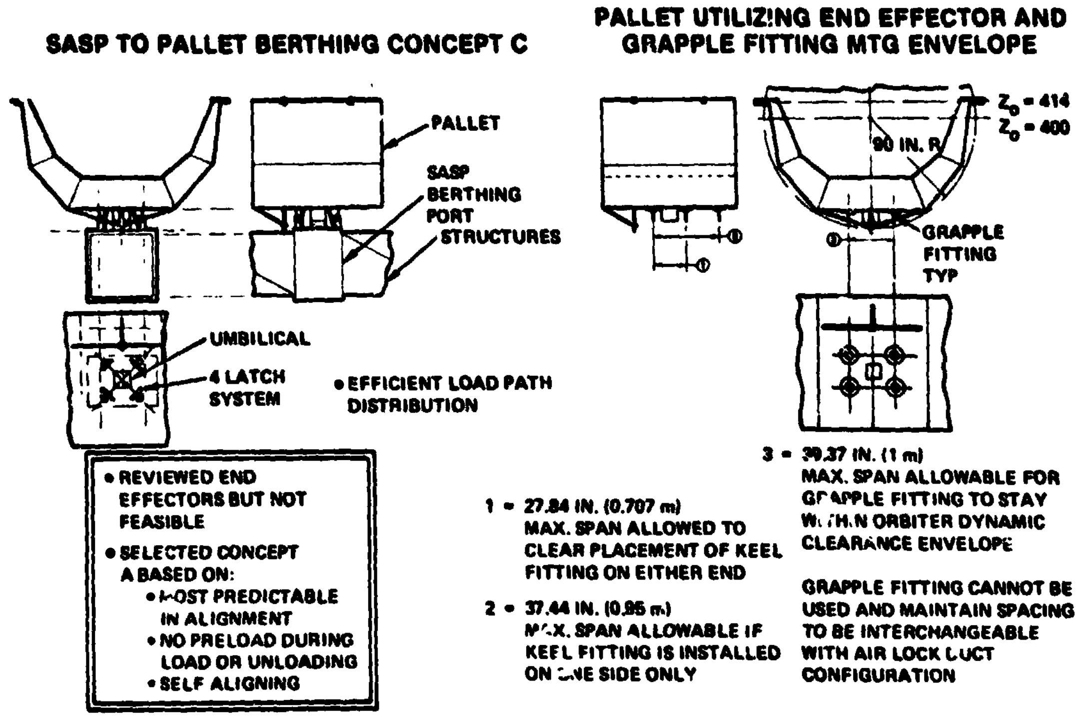


Figure 4.8.3-17 SASP to Pallet Berthing Interface Concepts (Continued)

Concept "A" is bottom-mounted with a three point latching system. It has one latching leg longer for initial engagement, which is a fixed spherical ball for pallet rotational indexing. The other spherical balls are on eccentric center to allow for manufacturing and assembly tolerance and for thermal movements.

Concept "B" is also a three-point latching system, the keel fitting is utilized and latched, and the other two points are identical to Concept "A".

Concept "C" is a four latch system with a latching concept similar to the Orbiter trunnion latches.

Concept "D" used RMS end effectors and grapple fittings. There were limitations on the span locations due to grapple fitting length interferring with the Orbiter radial clearance envelope.

The trades indicated that Concept "A" met the Orbiter clearance envelope, berthed easily, and had thermal compensation features. Also, the concept will adapt universally for Orbiter berthing, and payload berthing, and be compatible w:.h the RMS operational limits.

4.8.4 Conclusions and Comments

Trades wer performed in the mechanical design to resolve key issues and select design concepts for platform mechanical elements.

The platform arm tradeoff compared the various concepts for fixed, expandable and hybrid designs. A fixed truss concept was selected for First Order Platform and this same fixed truss in conjunction with a telefold expandable concept is recommended for the Second Order Platform. The Second Order Platform arms are launch configured with all three trusses in line. This results in reliability of deployment, simplicity of deployment mechanism, and requires no assembly on-orbit.

The tolerance study indicated that the total error varied between 3 to 6 arc min for yaw and roll and 15 to 17 arc min in pitch which is not considered a significant selection driver. So the selection of the truss configuration was selected due to simplicity, low cost, reliability and low weight. The selection indicated the fixed and telefold concept and met the majority of its objectives.

Bottom-mounting for the pallets was selected to maintain continuity from first to second order platforms, to avoid loss of payload bay useable length and to minimize dead-ended hardware development.

A service routing concept is recommended which only has connections at the berthing ports. Lines and tubing will be looped and restrained in the stowed

position and be automatically deployed when the truss is deployed. Convoluted tubing is used; it is continuous and requires no swivel joint.

A support module configuration was selected which allows folding of the cross-arms for launch compaction but is fully auto-deployable. This concept can be fully assembled in and checked out on the ground.

Arms can be rotated in certain operations on-orbit to allow loading and unloading of payloads.

Section 5

PLATFORM CONCEPTUAL DESIGN

(Task 5)

5.1 INTRODUCTION

In this task, the platform concepts are finalized based on early, general concepts defined in Task 1, drivers identified in Task 2, Power System interfaces defined in Task 3, and refinements developed as the results of trades performed in Task 4. For reference purposes, the resources made available to payloads via the Platform, are listed in Figure 5.1-1.

POWER
(AT THE PALLET)
- ~~5 kW$_{AVG}$ 7.5 kW$_{PEAK}$~~
- 28 VDC
- 120 VDC
- 20 KW AVG - 30 PEAK (CHANGED AT FINAL BRIEFING)

THERMAL CONTROL
- 2 kW REJECTION LOCAL
- TBD kW REJECTION CENTRALIZED
- CRYOGEN REPLENISHMENT
  - LITERS LIQUID HELIUM
  - LITERS LIQUID NITROGEN

DATA
- FORMATTING
- STORAGE – 8 X 10^{10} BITS
- PROCESSING
- TRANSMISSION
  - 220 MB/S
- TIME REFERENCE

STABILITY AND POINTING
- ACCURACY < 2 DEG
- STABILITY < 0.1 DEG
- ORIENTATION
  X-POP; Y-PSL; Z-IOP

VIEWING
- CONTINUOUS EARTH OBSERVATION
  - NADIR
  - LIMB/MAGNETIC PROVISIONS
- LIGHT-SIDE SOLAR VIEWING
- CONTINUOUS CELESTIAL VIEWING
  - LONG-TERM VISIBILITY WINDOW
- ANTI-EARTH VIEWING PROVISIONS

ORBITER SERVICES
- DELIVERY (POSSIBLE SHARED LAUNCH)
- MAINTENANCE – 6-MONTH INTERVALS
- RETRIEVAL
- RESUPPLY – 6-MONTH INTERVALS
- DATA COLLECTION – 6-MONTH INTERVALS
- INSTRUMENT CALIBRATION AND SET UP

COMMAND AND CONTROL
- EXPERIMENT SCHEDULING
- EXPERIMENT POINTING AND POINTING-SYSTEM CONTROL
- GROUND COMMAND LINK

Figure 5.1-1 SASP Payload Support Resources

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5.2 CONFIGURATION

5.2.1 Introduction

This section presents the integrated products of Study Tasks 1, 2, 3, and 4 relative to the platform configuration. It begins with an early concept for the Second Order Platform which was the only concept addressed until midterm. System-level guidelines were established early in the study and continually refined or modified as the study definition and direction developed. Configurations were developed based on the system-level guidelines, requirements, subsystem trades, and design drivers resulting from Study Task 2. These design drivers included, for example, payload field-of-view requirements, payload size and shape, payload servicing and staytime, Orbiter berthing, and dynamic environment. The concept evolution described in this section reflects the lessons learned as related to the key issues addressed during each of the study tasks.

5.2.2 Early Study Concept for Second Order Platform

The integrated concept shown in Figure 5.2.2-1 and shown in deployment in Figure 5.2.2-2, is an early representative configuration developed for multi-discipline platform. The concept incorporates ground-assembled, totally space-deployed beams with an integrated support module. Each structural beam incorporates a rotary joint enabling the Platform to provide multi-viewing capability.

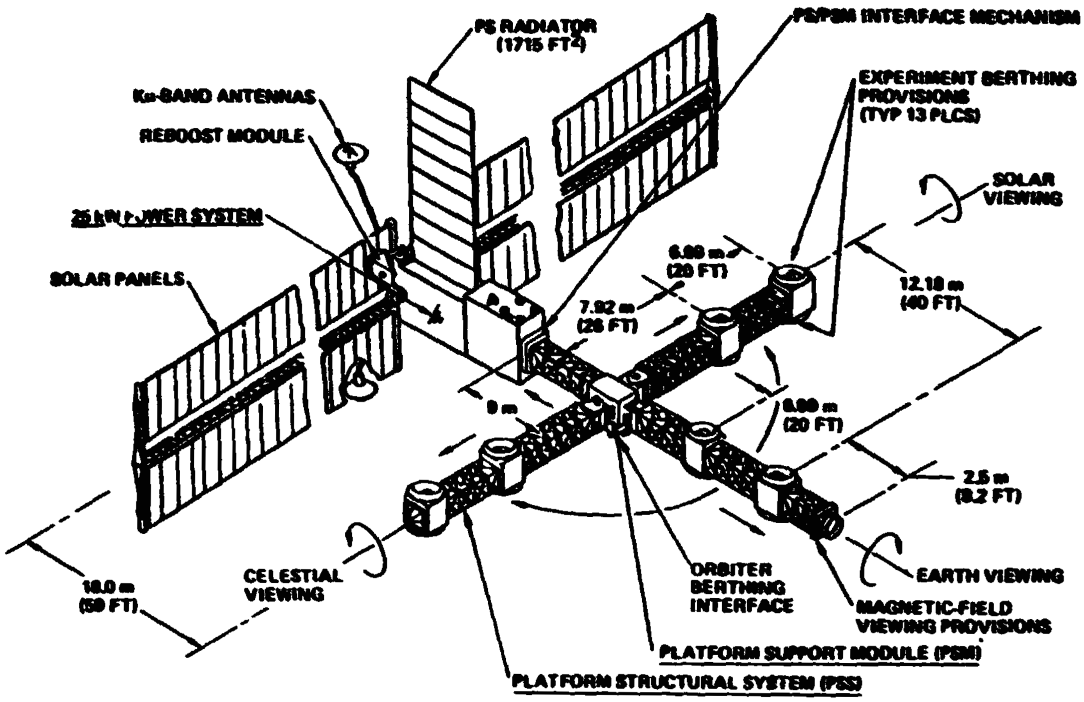


Figure 5.2.2-1 Science and Applications Space Platform Reference Configuration (Deployed)

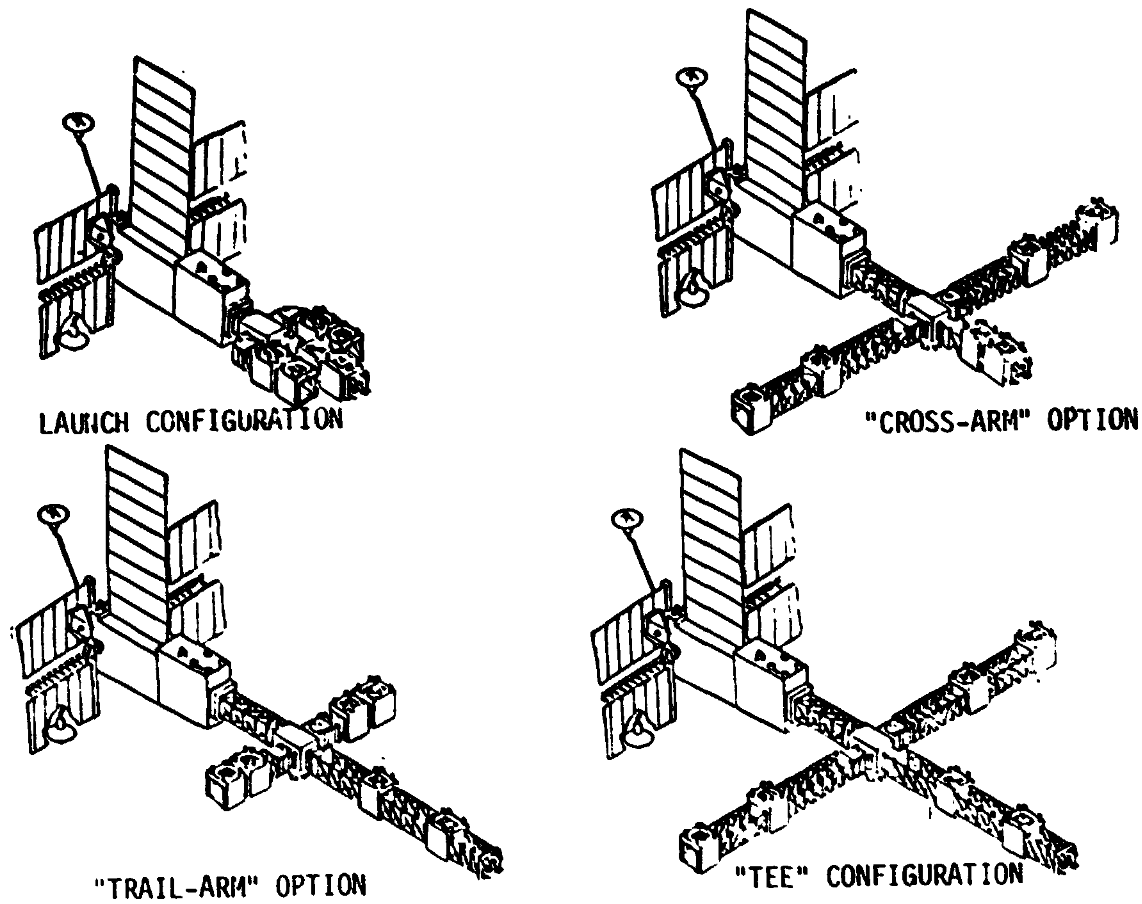


Figure 5.2.2-2 Reference Configuration Deployment Options

The arms are folded during launch and restrained by integral support structures. Each arm has multiple pallet berthing ports and are spaced for ease of replacement and for minimizing viewing obscuration of adjacent pallets. The support module provides centralized services for the Platform and incorporates the rotation mechanism for the structural arms. Electronics systems are packaged in removable avionics modules. The physical size of the Support Module resulted from torquer bar separation requirements and rotary joint designs.

The concept incorporates space expandable structural arms with an integrated Support Module. Each structural arm incorporates a rotary joint enabling multi-viewing capability. Swing-arm capabilities are incorporated in the cross-arm sections to permit compact stowage in the Orbiter.

Payload berthing provisions are provided at six arm locations. Each berthing module incorporates two back-to-back berthing mechanisms and umbilical panels. This redundancy permits multiple positioning of the Orbiter during on-orbit operations, as well as payload installation on both sides of the arm if required. The spacing shown between elements resulted from a cursory evaluation of clearances required to prevent interference between solar array/celestial and/or solar viewers, and between individual experiments as well as viewing requirements and RMS reach envelope. This configuration was addressed early in the study and later became designated as the "Second Order" Platform, which is now planned to follow the recently conceived "First Order" Platform which is described in the next paragraph.

5.2.3 First Order Platform Configuration

Based on direction received at mid-term, a mini-platform concept was developed based on a low-initial-cost, reduced complexity, and limited experiment capability approach. The First Order Platform, shown in Figure 5.2.3-1, represents a very compact early platform configuration to satisfy those requirements. The concept can be flown in various orientations as best suited for early payload combination. Consideration was given to end, side, and bottom mounting of payload pallets to the Power System berthing ports. Each option was evaluated against the simultaneous multiple viewing requirements in addition to the physical clearances required between payloads or between payloads and Power System elements as documented earlier in Section 4 of this report. The bottom mounted pallet was selected as the preferred method with a three-position ($0 \pm 90°$) arm with a 90° hinge.

The First Order Platform configuration, therefore, has three identical (except for indexing angles) structure arms. Each arm is 3.0 m long and interfaces

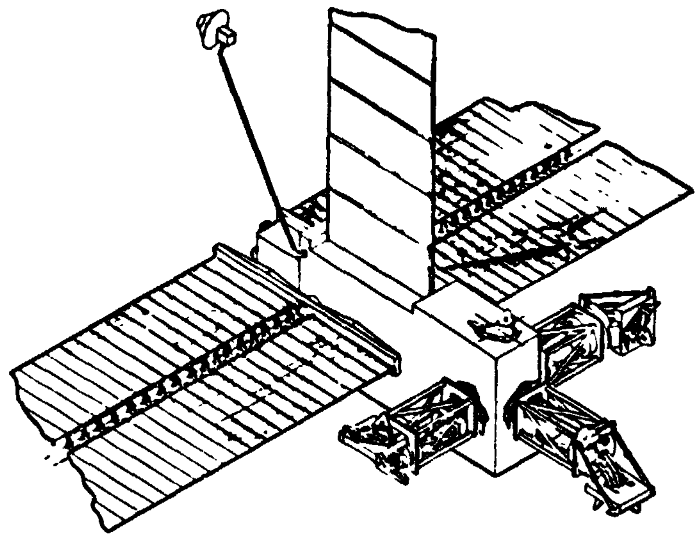


Figure 5.2.3-1 1st Order Platform

directly to the Power System +Y, -Y, and +X berthing ports. The Power System +Z port is utilized as a parking port during payload exchange. Each arm can place the payload in four positions with the +X and -Y arm rotating clockwise and the +Y arm rotating counterclockwise. Each payload interface panel incorporates an active pallet berthing mechanism with a deployable umbilical panel. The berthing mechanism is configured to accept a pallet assembly with a bottom-mounted passive interface. The four-position arm will allow the maximum viewing capability for this low cost First Order SASP.

5.2.4 First Order Platform Growth Configuration

Increased payload capability can be realized by the addition of a structural arm berthed to the Power System +Z port as shown in phantom on Figure 5.2.4-1 which also describes the capabilities of the unit.

Utilization of the Power System +Z por. for an operating payload element removes the First Order Platforms capability of providing parking facilities to enhance

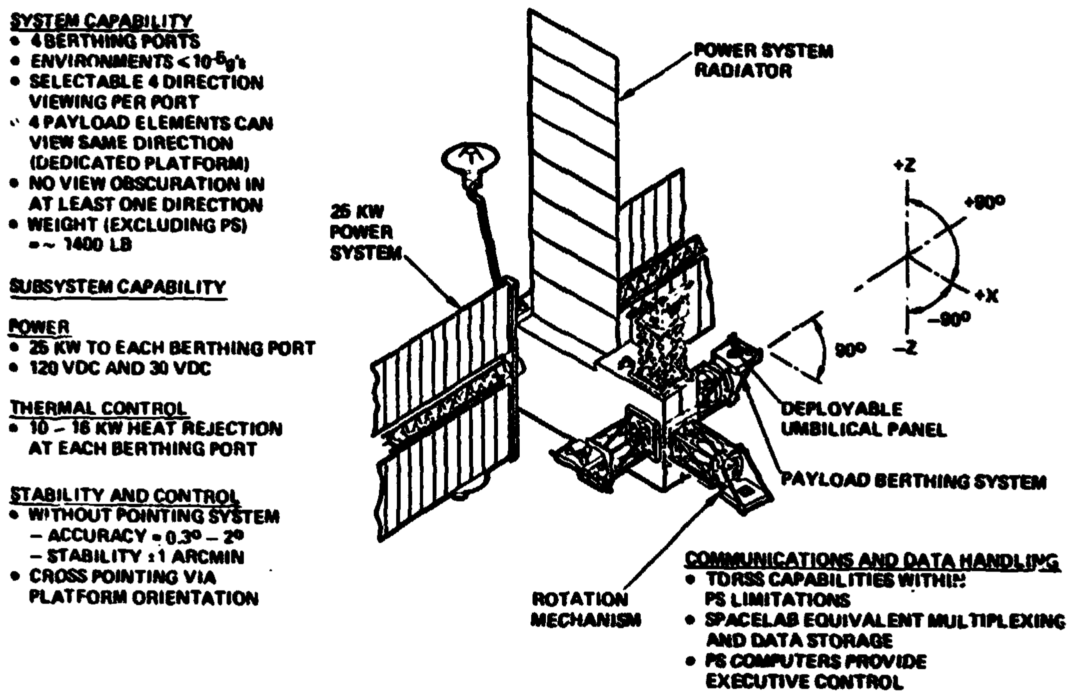


Figure 5.2.4-1 First-Order Platform

payload exchange. A cursory investigation identified two possible alternatives to accomplish on-orbit payload exchange with minimum impact on Orbiter operations. One alternative is the addition of a Power System mounted mini-RMS. This manipulator would accept a single payload from the Orbiter RMS and translate to a holding position. This would enable the Orbiter RMS to proceed with payload exchange. The second method would be to reserve space in the cargo bay as required to satisfy payload exchange.

Additional study will be necessary to evaluate the complex problem of on-orbit payload exchange in terms of equipment requirements, complexity cost, Orbiter stay-time, and impact on overall program cost.

5.2.5 Basic Second Order Platform

Our finalized concept for the Second Order Platform (the only concept addressed initially in the study) is shown in Figure 5.2.5-1 and Figures 5.2.5-2a, and b

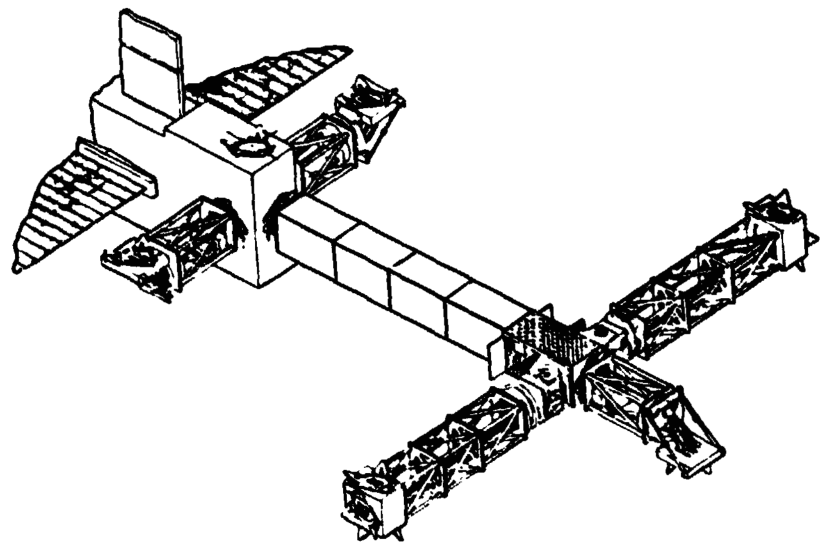


Figure 5.2.5-1 Basic 2nd Order Platform

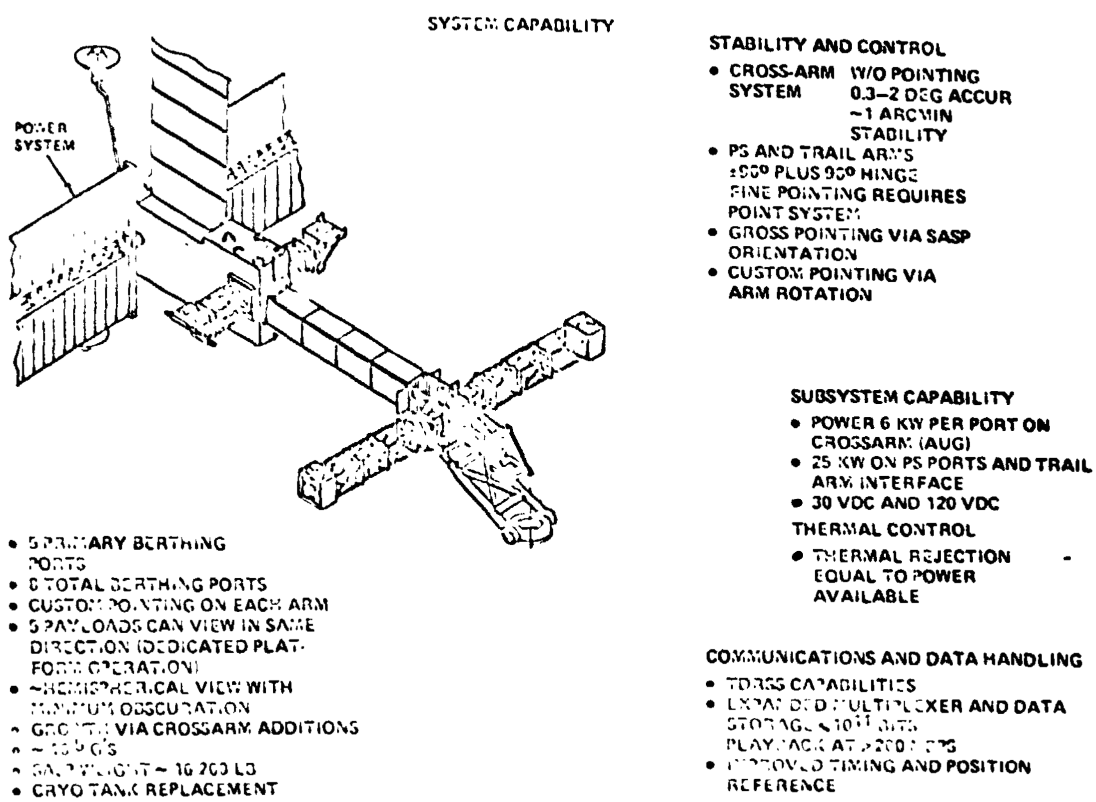


Figure 5.2.5-2a Second Order Platform

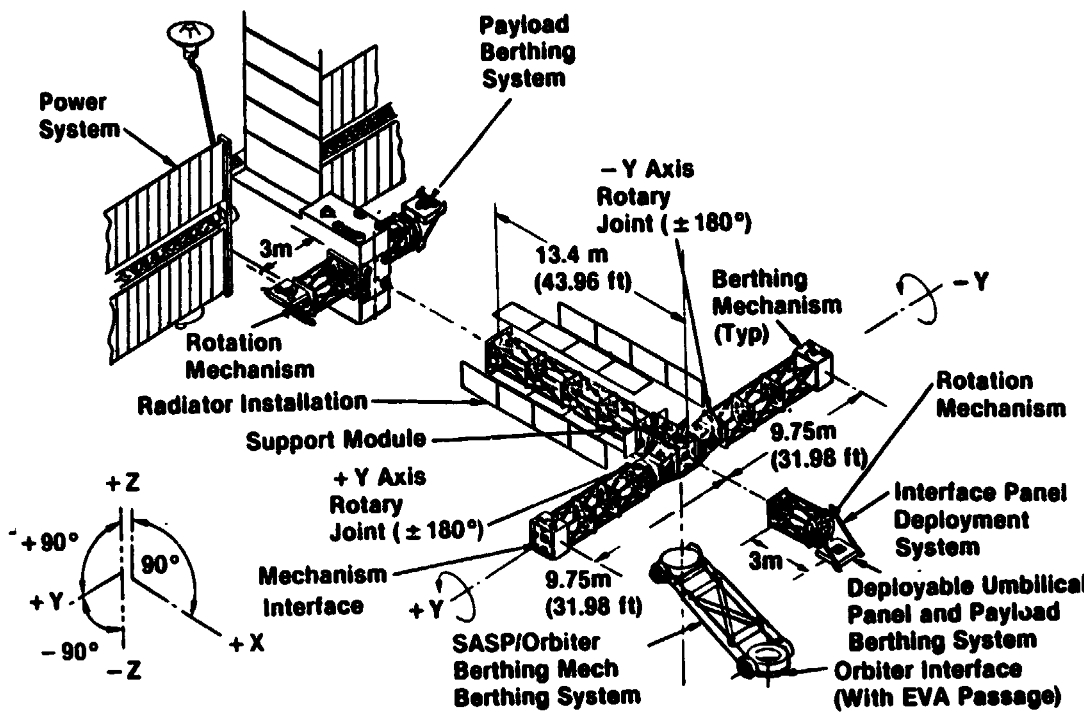


Figure 5.2.5-2b Basic Second Order Platform Elements

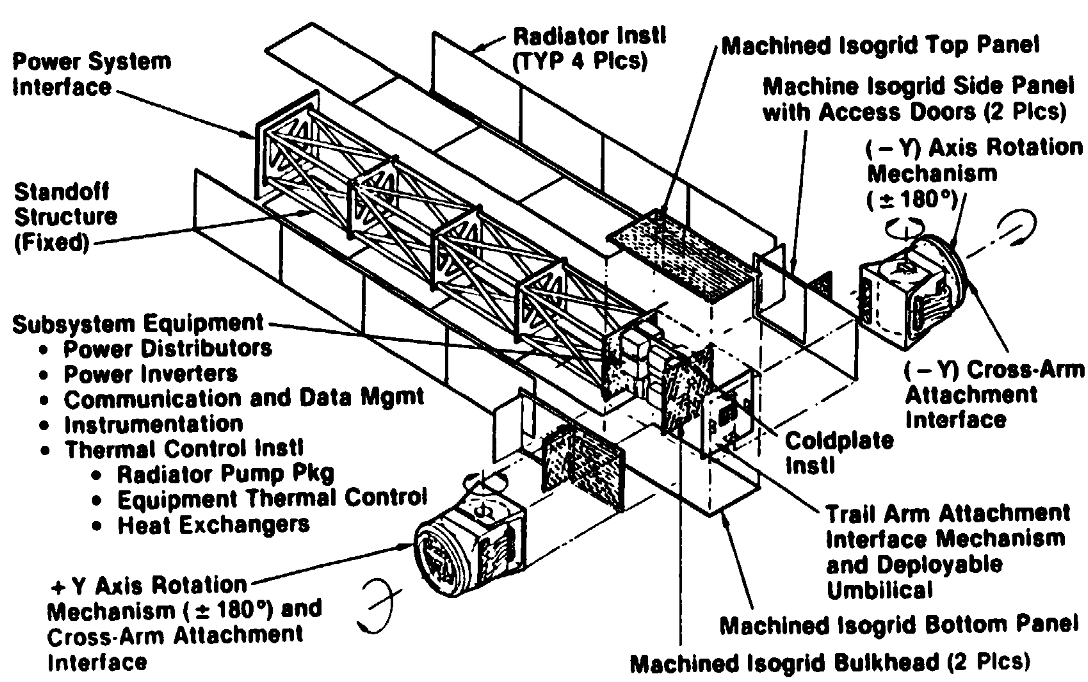


Figure 5.2.5-3 Platform Support Module Assembly

representing a significant extension of the 13.4 m standoff and support module assembly with two 9.75 m long cross-arms (see Figure 5.2.5-3). The support module assembly incorporates a 1.42 m x 1.52 m x 3.0 m long subsystem section which is sized to accommodate the subsystem components required to support platform experiments. These components are mounted on a central coldplate with access doors providing access for on-orbit servicing and replacement.

The (Y) axis rotation mechanisms are mounted to the isogrid core section. These mechanisms provide ±180° rotation for the cross-arm in addition to the 90° gimbal for cross-arm stowage during launch. The core section also incorporates berthing ports for Orbiter berthing and for the trail arm installation. The Orbiter port is passive and the trail arm port is active.

The SASP interface wiring and plumbing from the Power System to the appropriate connectors and umbilicals are routed along the tubular standoff structure. This structure also provides mounting provisions for the platform centralized thermal control radiator. The radiator is a series of panels mounted on the four sides of the structure. The standoff assures adequate clearance between the Power System solar arrays and platform mounted payloads. The support module also incorporates the SASP/Orbiter interface berthing mechanism and an active interface system on the (+X) axis to accept a trail arm installation.

The Basic Second Order SASP provides eight berthing port accommodations permitting custom pointing on each arm. The custom pointing features permit multiviewing simultaneously with minimum obscuration. The cross-arm assemblies are a hybrid fixed/deployable truss structure using 2.5/8" OD x 1/8" wall thickness graphite/epoxy tubes. The fixed section extends 9.75 m from center line. The configuration also permits all payloads to view in the same direction. The berthing boom (mounted underside of standoff) concept was

developed late in the study and a quick look concept was presented. This concept is a telescopic tubular truss which is a permanent part of the SASP and stowed whenever the Orbiter is not docked. Further trade study should be accomplished to determine other means of servicing the SASP and Power System without redocking. Capabilities are incorporated for the addition of extension kits which would support up to fourteen payloads, as defined in the next paragraph.

5.2.6 Extended Second Order Platform

A modular growth platform capability is incorporated by extension of both crossarms and the addition of a trail arm section. The deployable section is a telefold design (see Figure 5.2.6-1) described in detail earlier in Section 4.

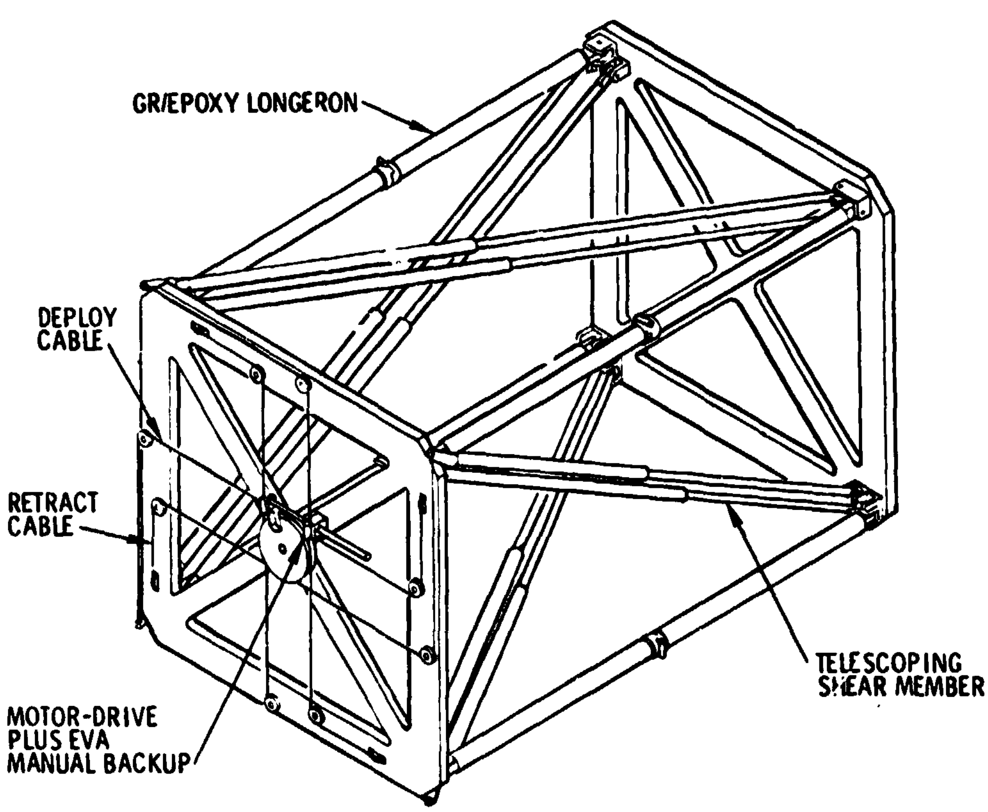


Figure 5.2.6-1 Telefold Deployable Truss

Each arm incorporates two berthing stations. The inner station incorporates two active payload berthing systems. The outer station provides one active payload port and one passive Orbiter berthing port. The Orbiter port is a temporary port used for payload exchange and incorporates limited services. The resulting configuration shown in Figure 5.2.6-2 through Figure 5.2.6-4 has the capability to carry a total of fourteen payloads. Figure 5.2.6-5 outlines the system capability obtained with the addition of the extension kits. The extension kits, consist of one +Y cross-arm extension, one -Y cross-arm extension, and one trail arm extension kit. The cross-arm payload accommodations are increased 100% with the addition of two 13.5m large structural extensions. These extensions are a telefold design selected to minimize cargo bay usage. If cargo bay accommodations warrant, a fixed structural design of equal length could be incorporated. Earth resources experiments requiring 360° rotation can be accommodated on the trail arm extension. The trail arm extension incorporates a thermal control system thus eliminating the requirement to accommodate fluid through the 360° rotary joint. The trail arm extension also incorporates an active berthing system on the (+X) axis to accept the first order payload structural adapter. Two payloads can be accommodated on the trail arm extension making a total of 13 payloads accommodated by the Extended Second Order Platform with one parking port remaining for payload changeout. Figures V and W are configuration and Shuttle interface layouts for this second order extended case.

5.2.7 Double Solid Trail Arm Configuration

If mission plans indicate the need for supplemental trail arm capabilities for (1) additional payloads, or (2) greater separation from the cross-arms, an additional trail arm kit could be added as shown in Figure 5.2.7-1.

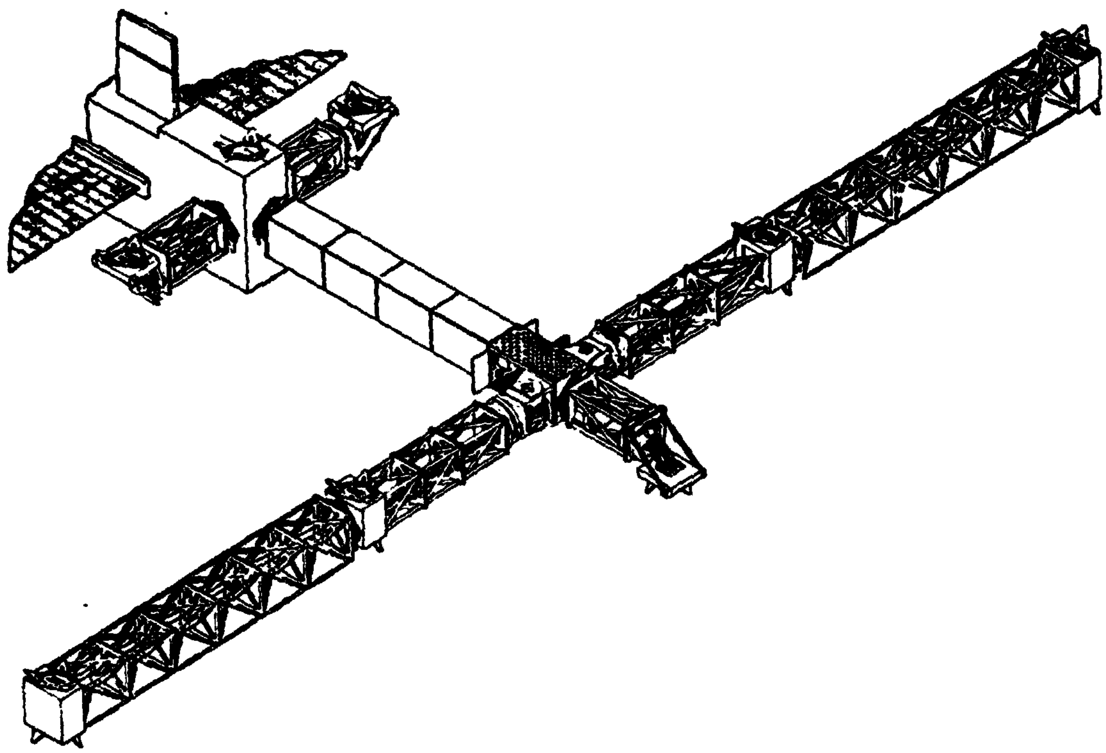


Figure 5.2.6-2 Ex+ended 2nd Order Platform

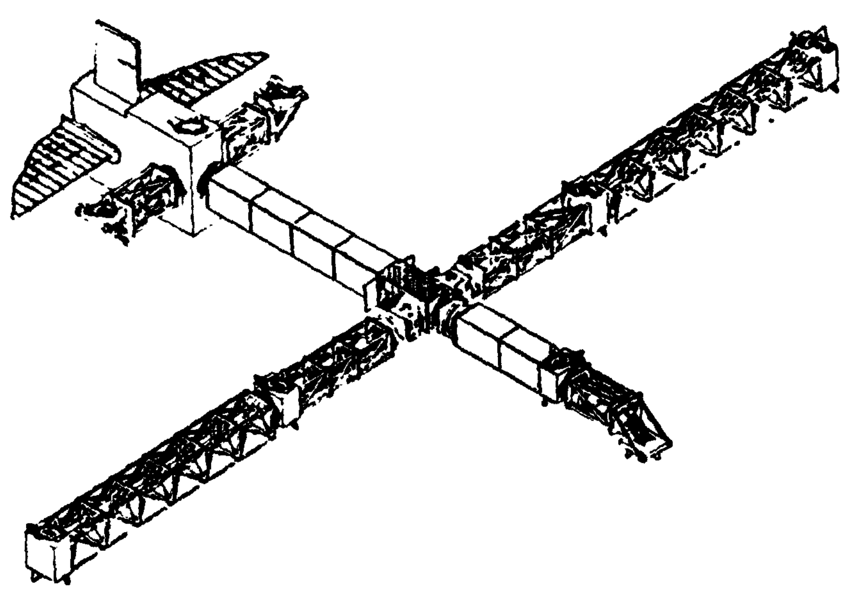


Figure 5.2.6-3 Full Capacity 2nJ Order Platform

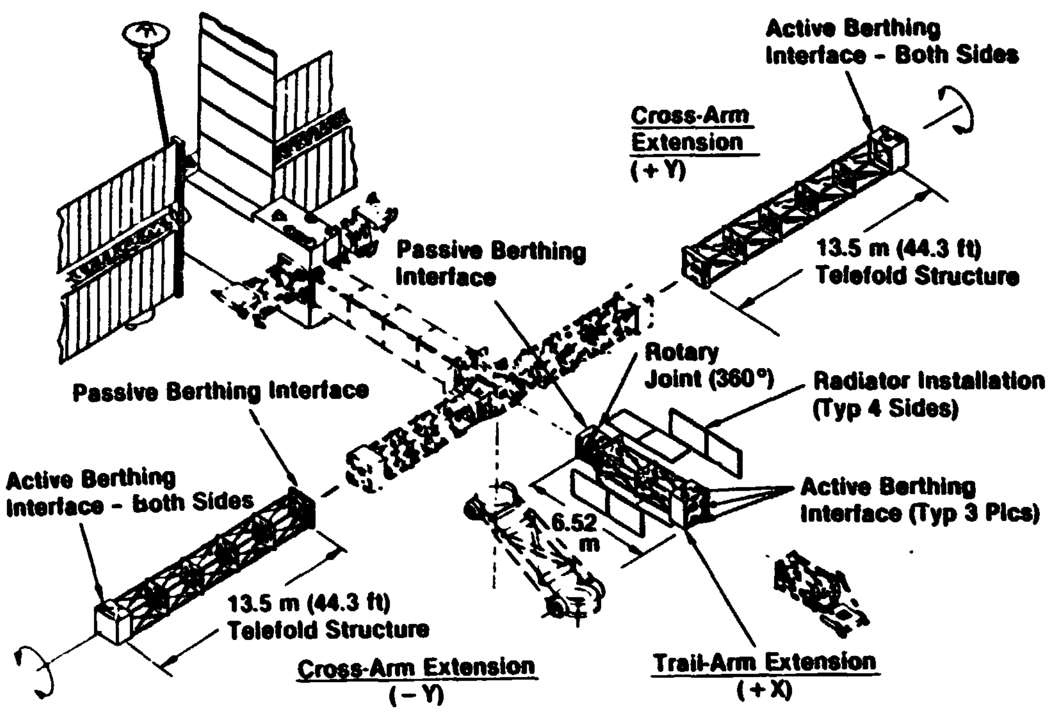


Figure 5.2.6-4 Second Order Platform Extension Kits

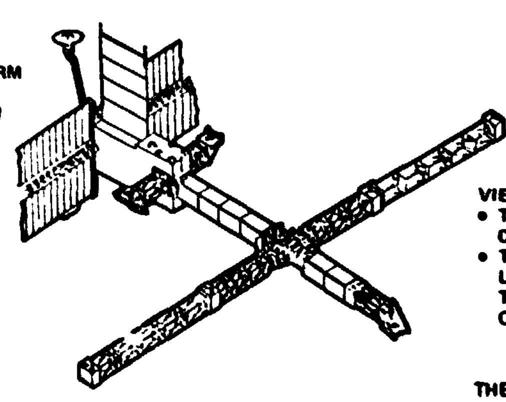


Figure 5.2.6-5 Extended Second Order Platform

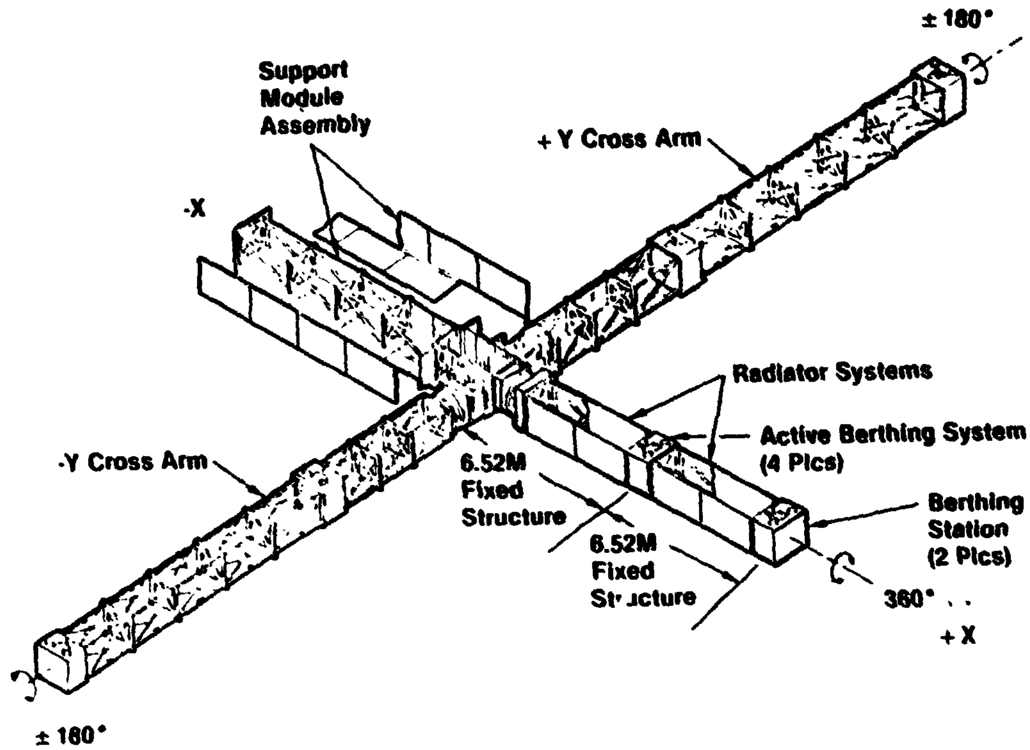


Figure 5.2.7-1 Platform "Tee" Configuration

5.2.8 Triple Telefold Trail Arm

For single-view dedicated missions, earth for example, and where very large multiple payloads desire uni-viewing, the triple telefold configuration shown in Figure 5.2.8-1 may be employed.

5.2.9 Layout Drawings

Drawings for the Second Order Platform (basic without first order mini-arm) are shown in Figures 5.2.9-1 and 5.2.9-2.

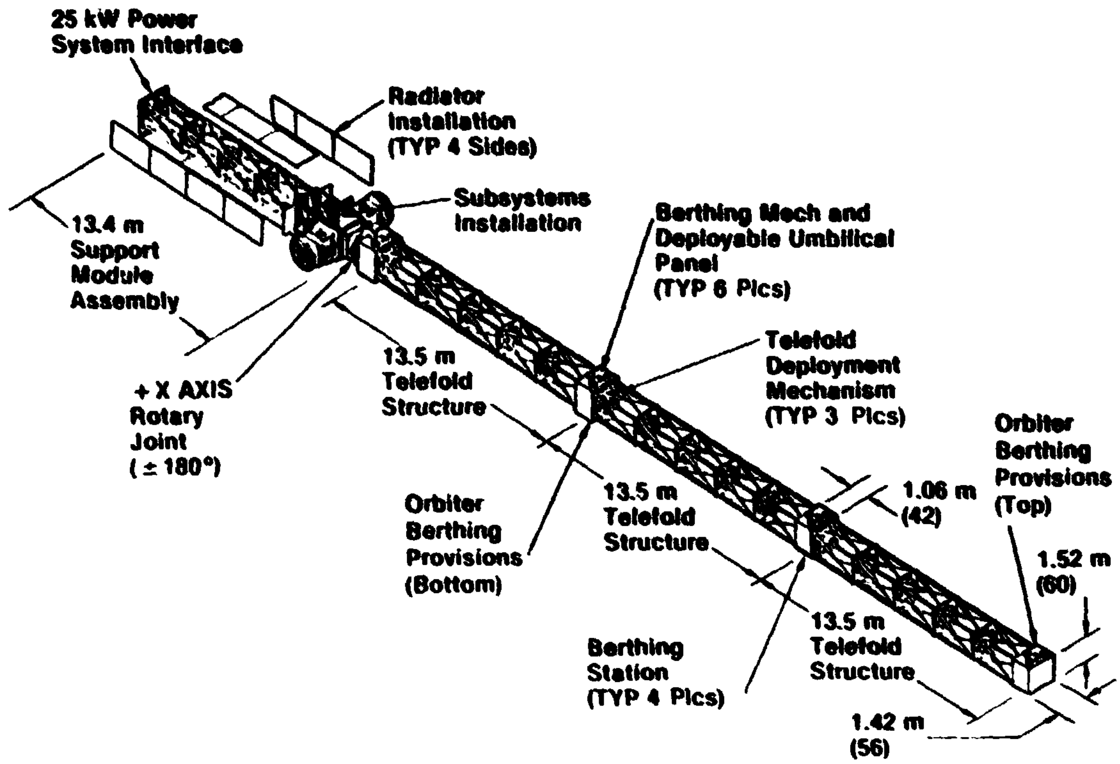
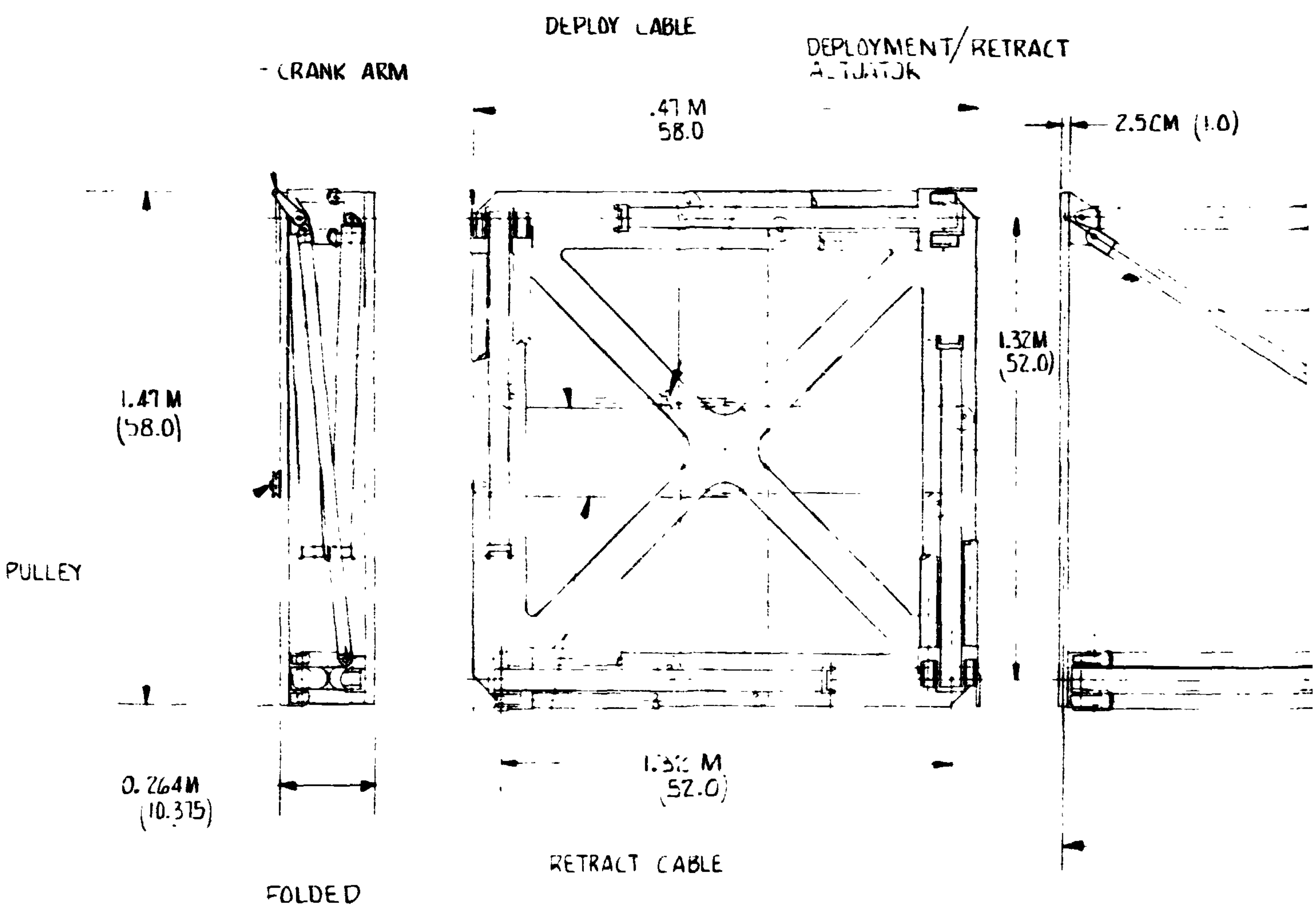
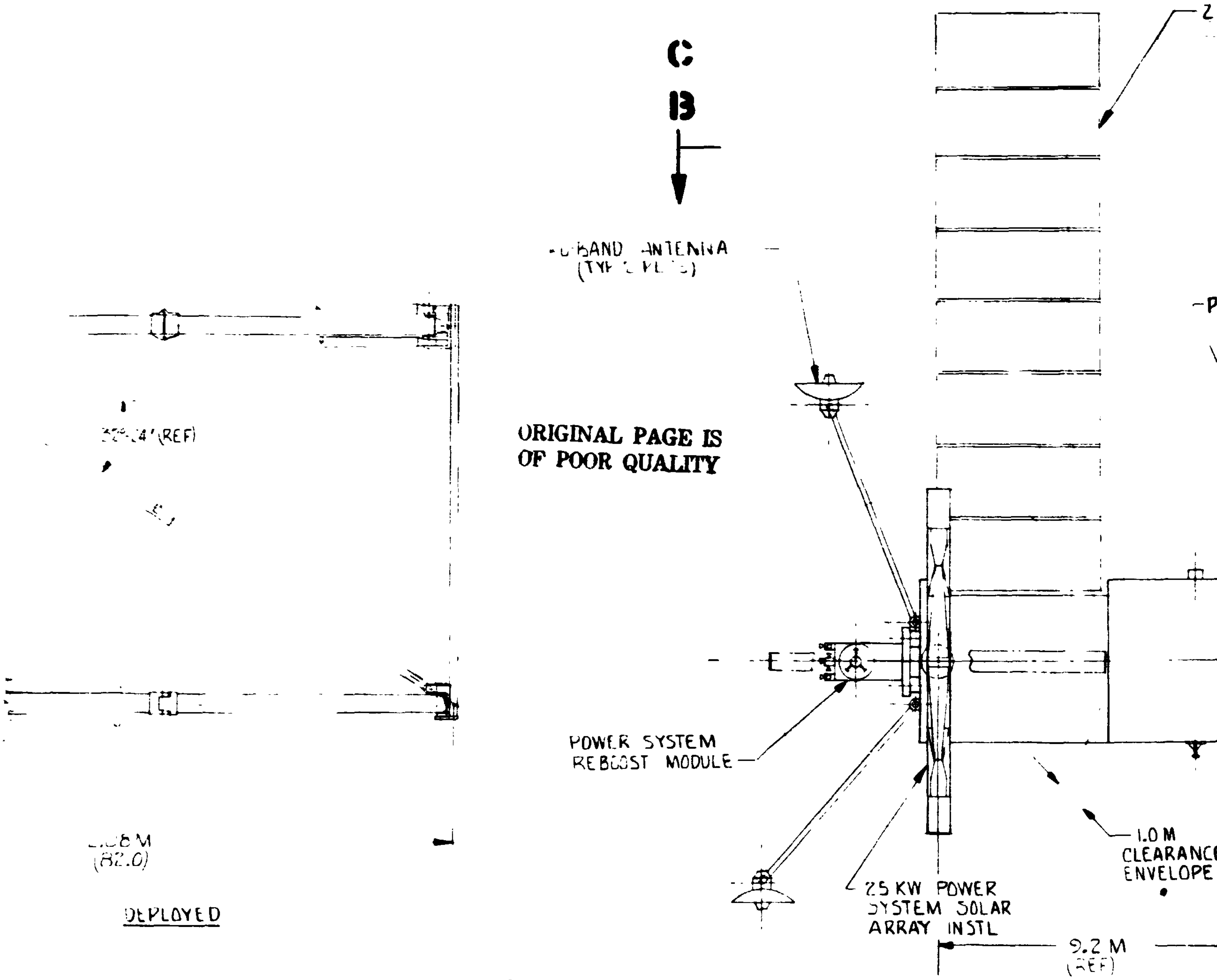


Figure 5.2.8-1 Platform Trail-Arm Configuration

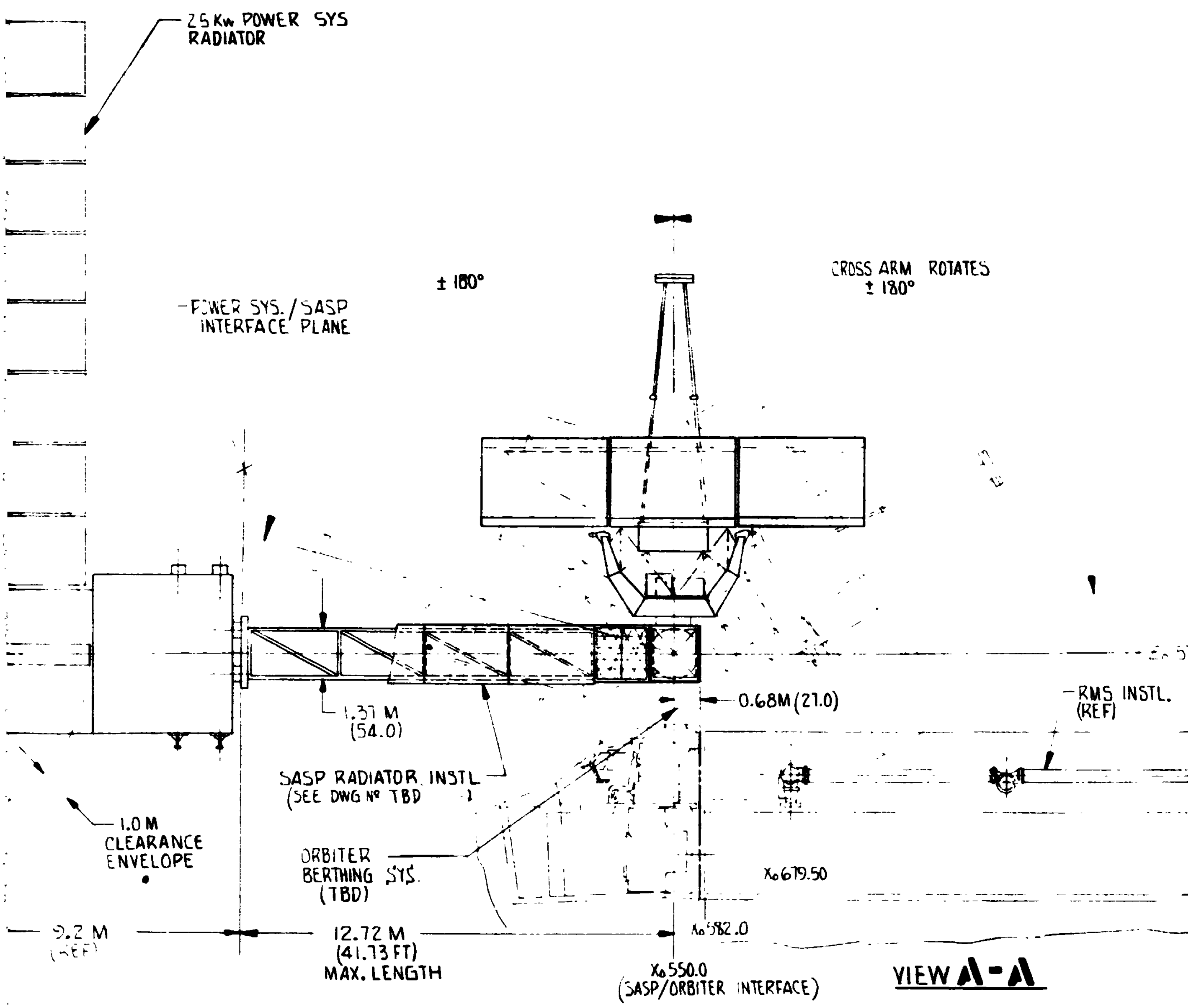


SECTION E-E
TELEFOLD STRUCTURE
SCALE 1/10

FOLDOUT FRAME



FOLDOUT FRAME 2



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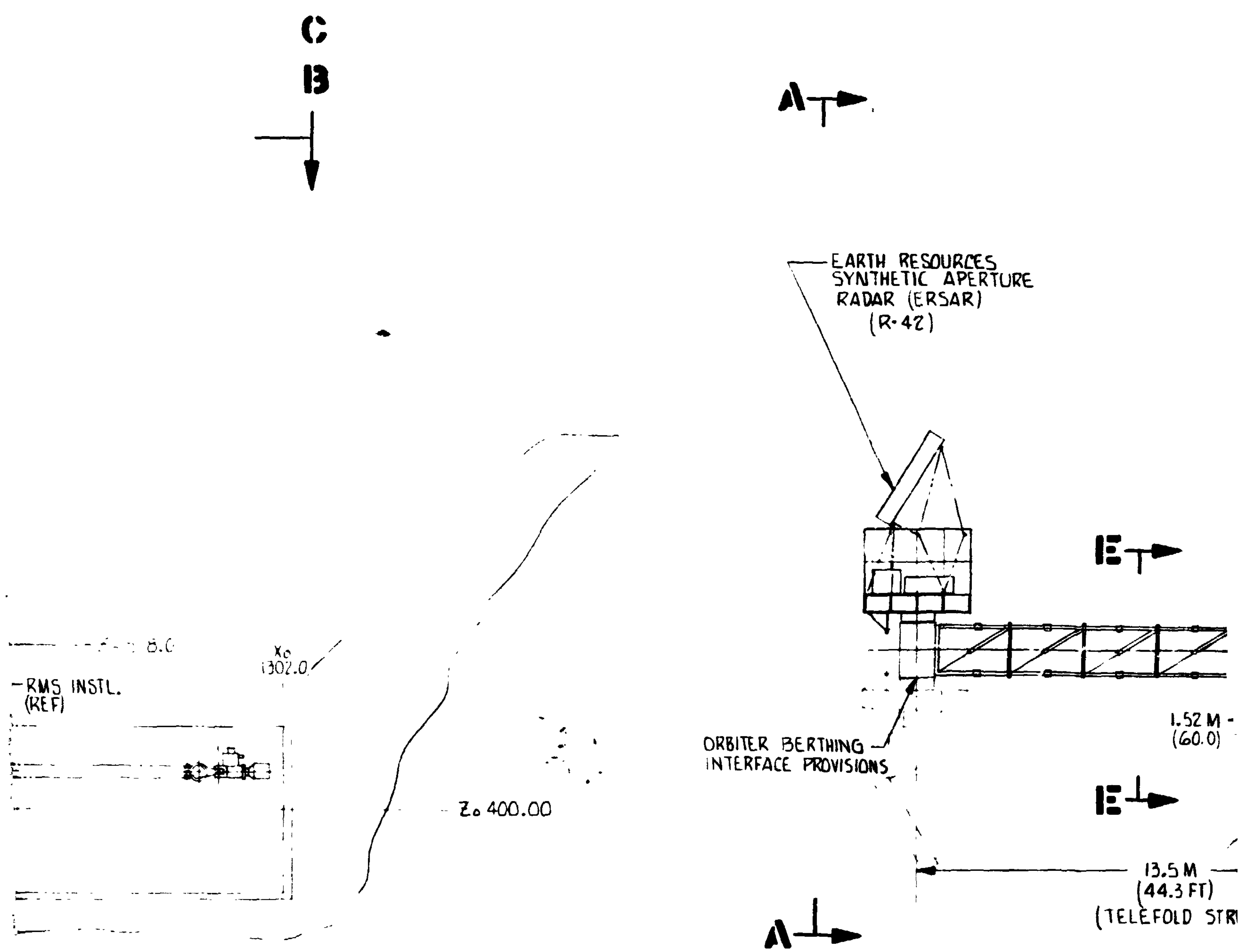
FOLDOUT FRAME 3



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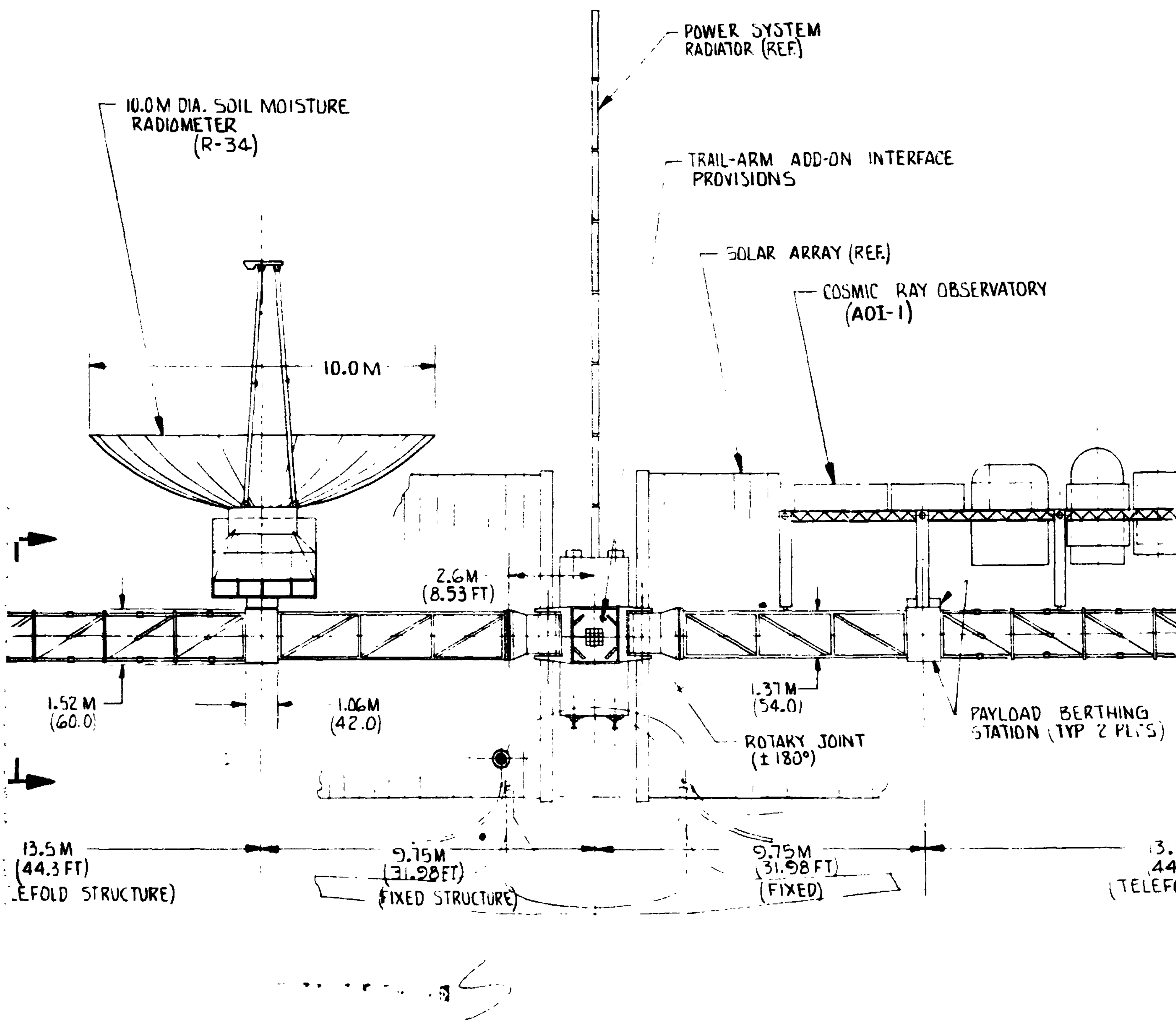
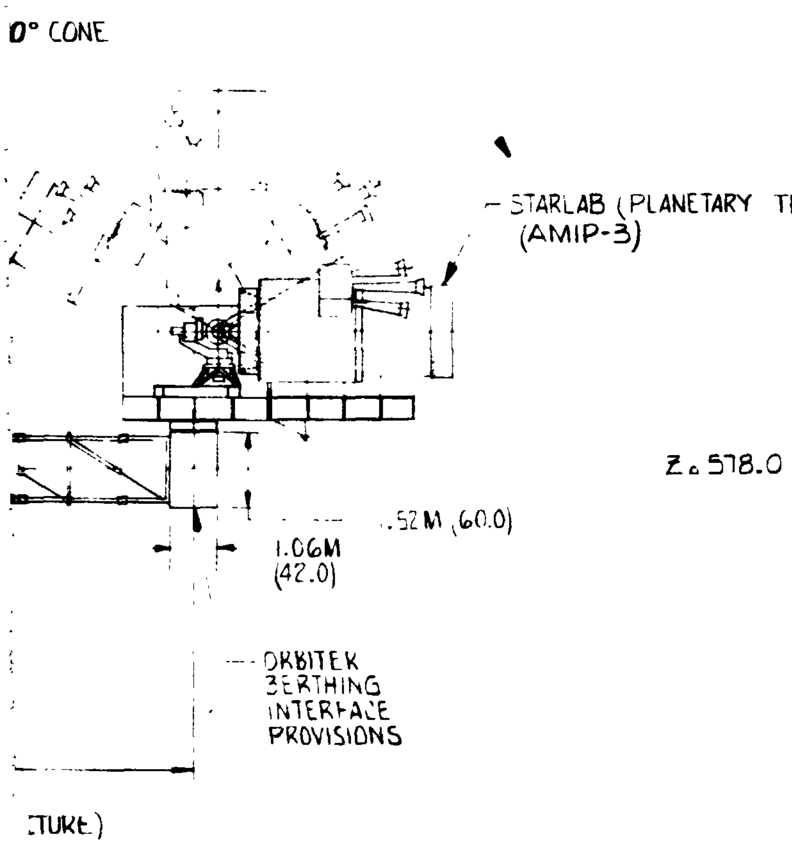
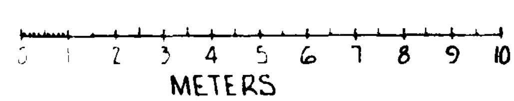


POWER SYSTEM RADIATOR (REF.)
10.0 M DIA. SOIL MOISTURE RADIOMETER (R-34)
TRAIL-ARM ADD-ON INTERFACE PROVISIONS
SOLAR ARRAY (REF.)
COSMIC RAY OBSERVATORY (AOI-1)
10.0 M
2.6 M (8.53 FT)
1.52 M (60.0)
1.06 M (42.0)
1.37 M (54.0)
ROTARY JOINT (± 180°)
PAYLOAD BERTHING STATION (TYP 2 PLCS)
13.5 M (44.3 FT)
EFOLD STRUCTURE)
9.75 M (31.98 FT) (FIXED STRUCTURE)
9.75 M (31.98 FT) (FIXED)





CONTRACT NO			MCDONNELL DOUGLAS ASTRONAUTICS CO. WESTERN DIVISION HUNTINGTON BEACH, CALIFORNIA
ORIGINAL DATE OF DRAWING			SCIENCE & APPLICATIONS SPACE PLATFORM
PREPARED	G KING	20 MAR 80	CROSS ARM CONFIGURATION
CHECKED			
ENGINEER			
DESIGN ACTIVITY APPROVAL			SIZE: ; CODE IDENT NO.: 18355; DRAWING NO.: GSK 032080 SASP
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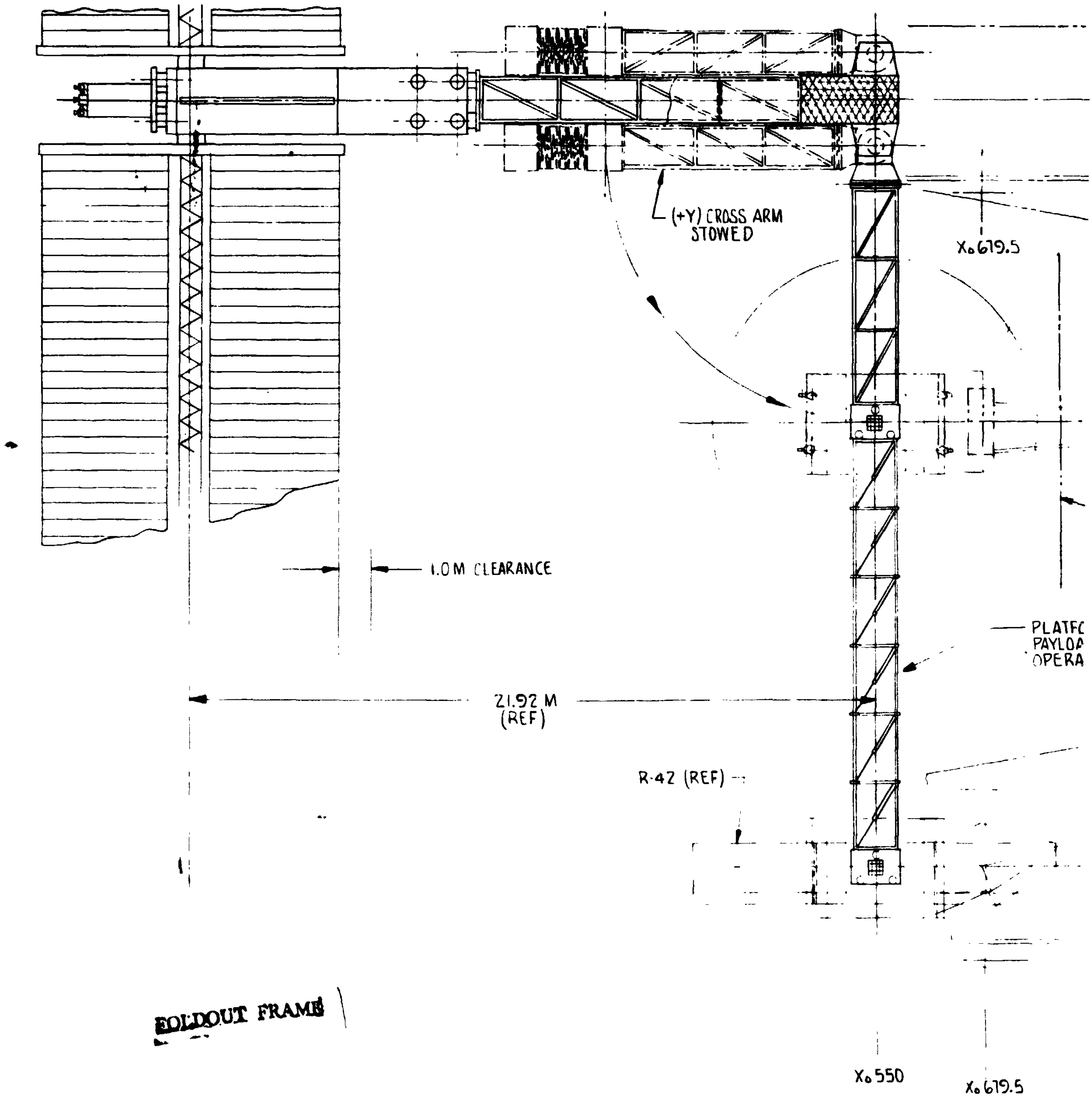
Figure 5.2.9-1. Second Order Cross Arm Configuration



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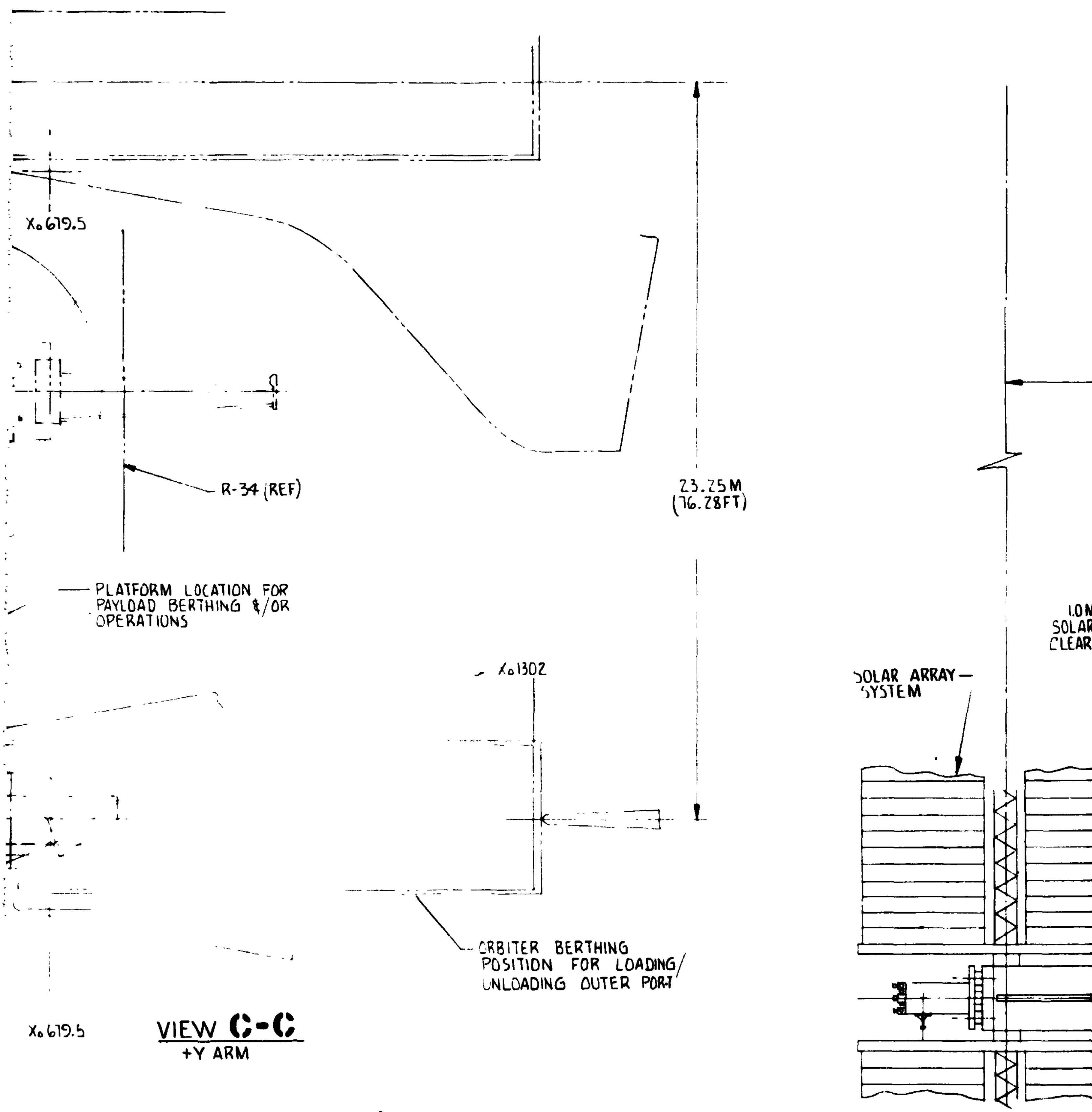
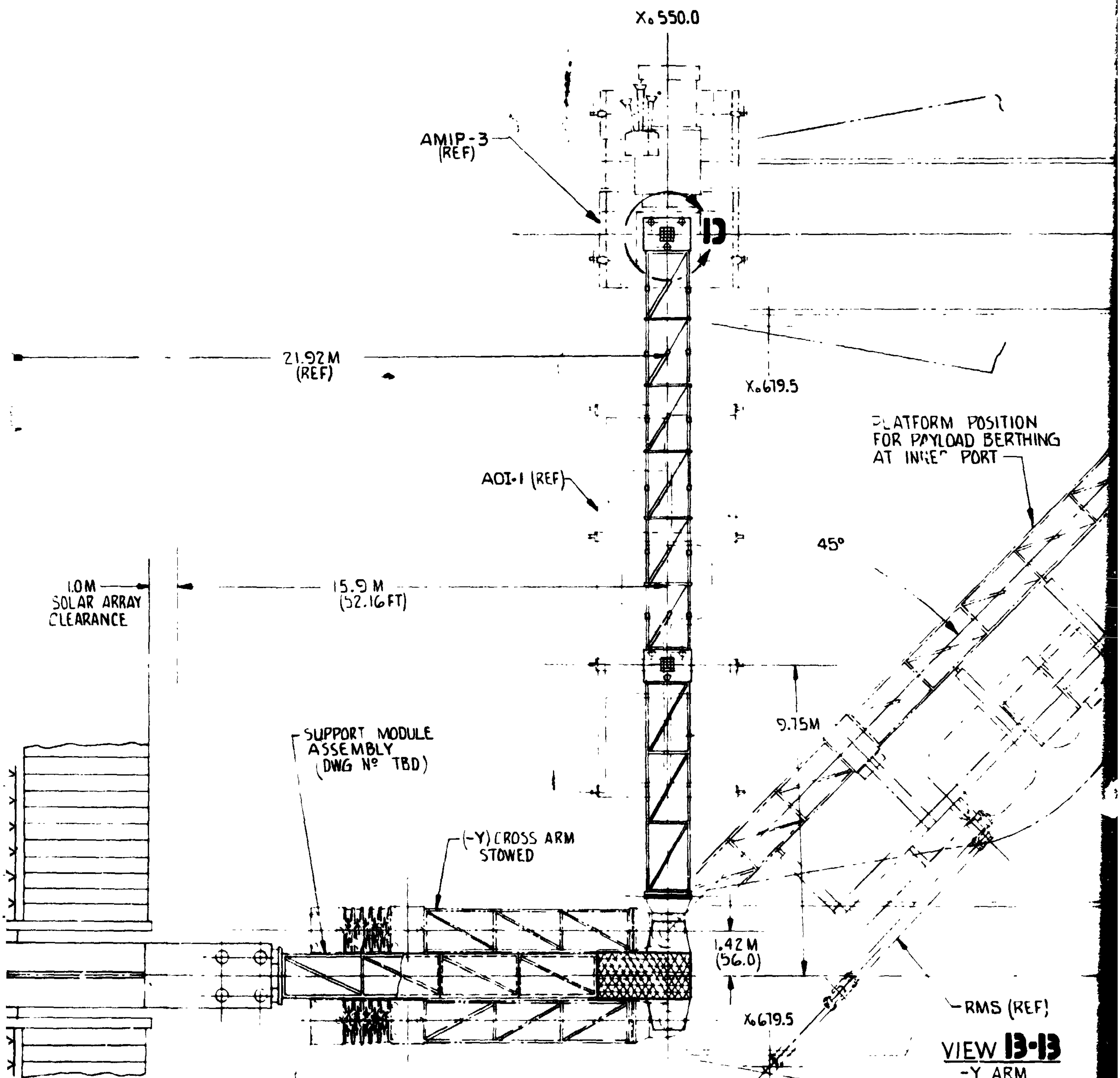
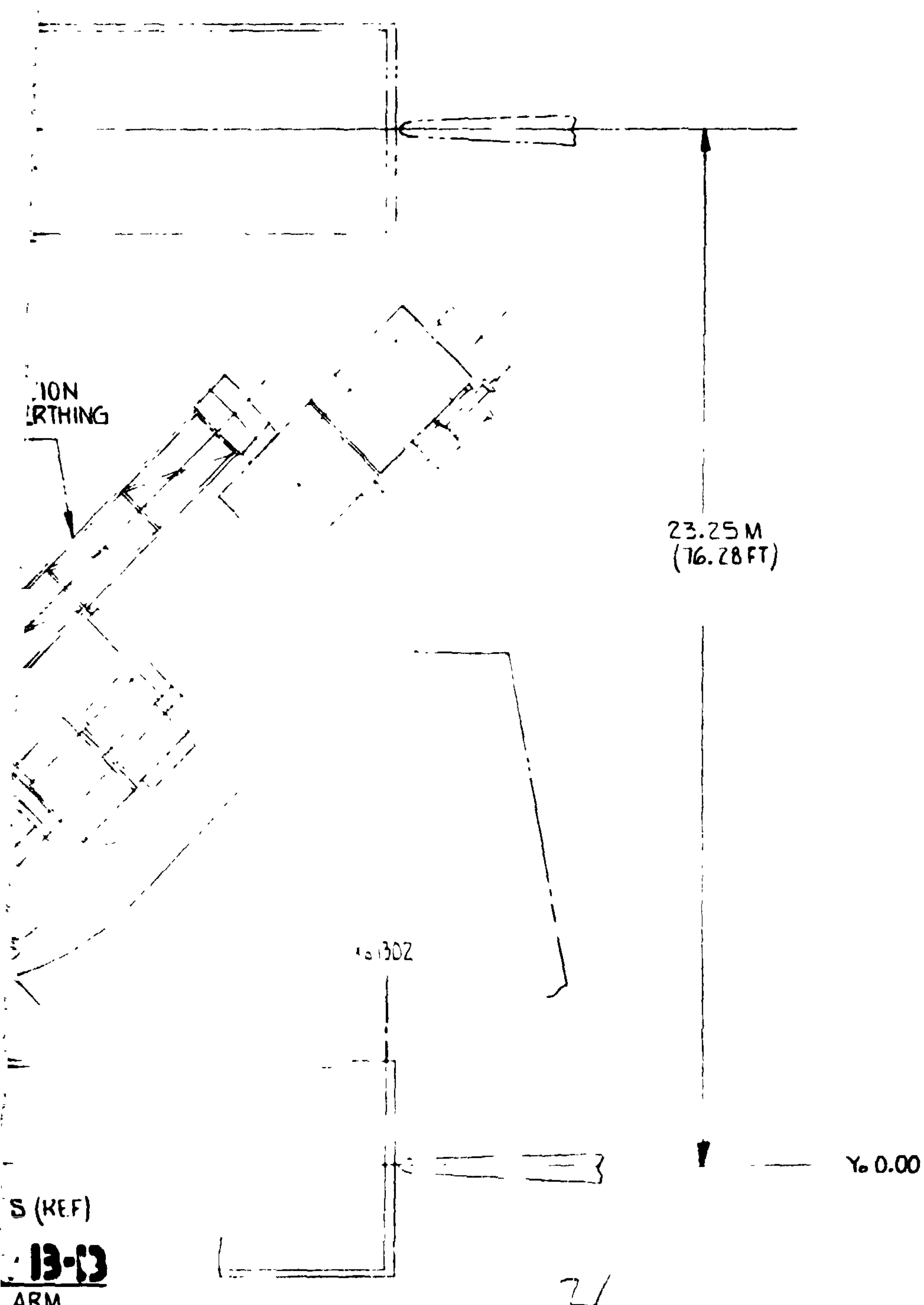


VIEW C-C
+Y ARM

FOLDOUT FRAME 2

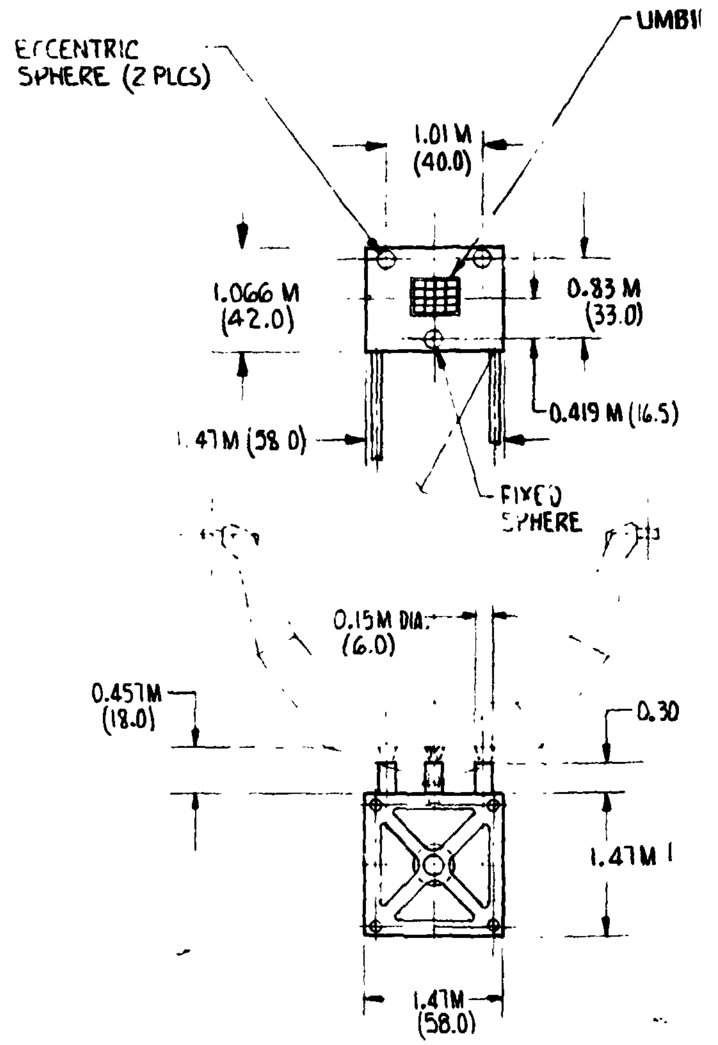


FOLDOUT FRAME



S (REF)

13-13
ARM



VIEW D
(BERTHING STATION - TYP)
SCALE 1/40

FOLDOUT FRAME

7

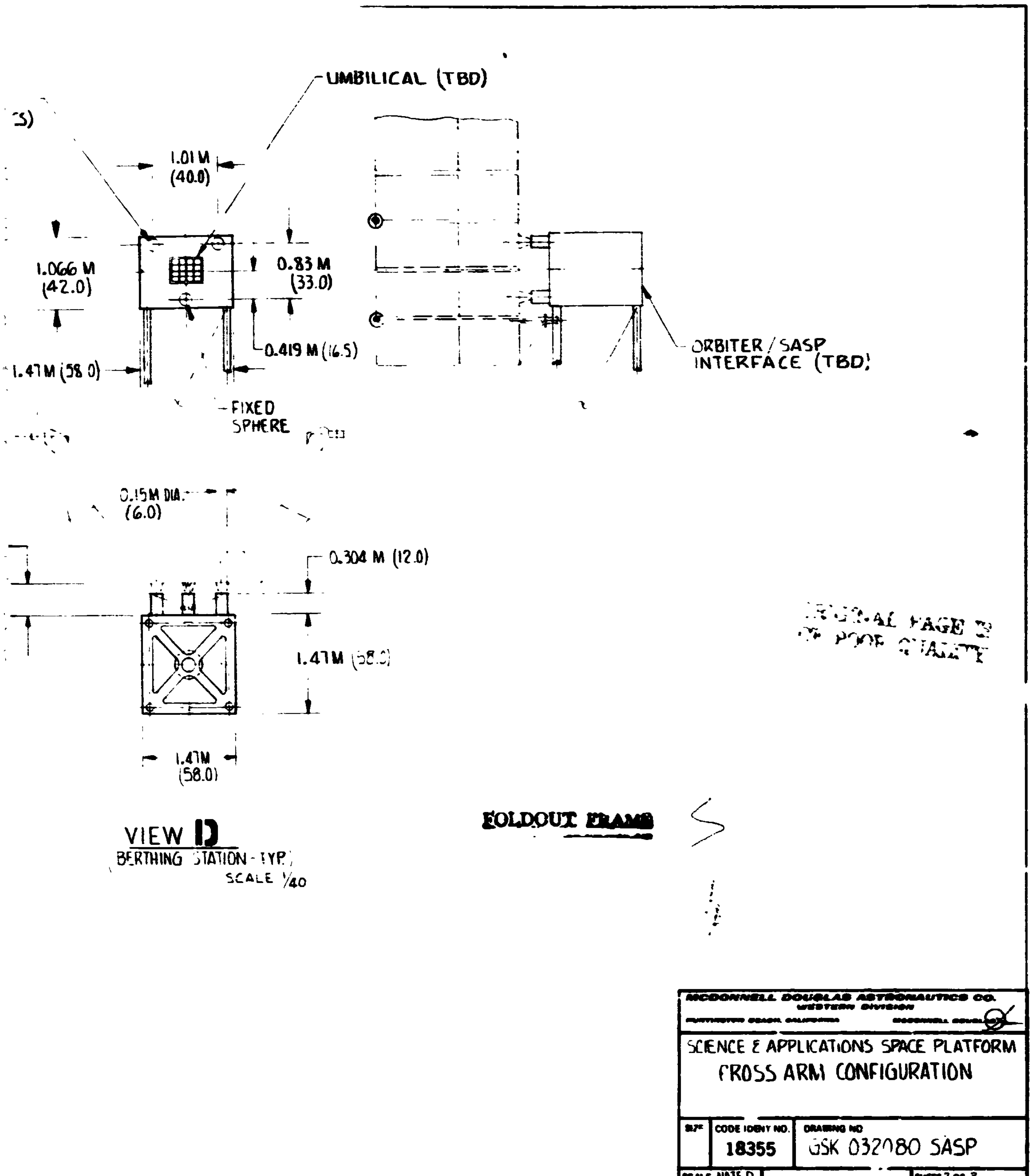


Figure 5.2.9-2. Second Order Cross Arm Configuration

5.3 MECHANISMS

5.3.1 Introduction

Tne Second Order Platform mechanisms were studied exclusively until direction was given at midterm to develop a first order concept. For clarity, however, the first order mechanical aspects are given first in this section.

5.3.2 1st Order Platform Payload Berthing Structure and Mechanism

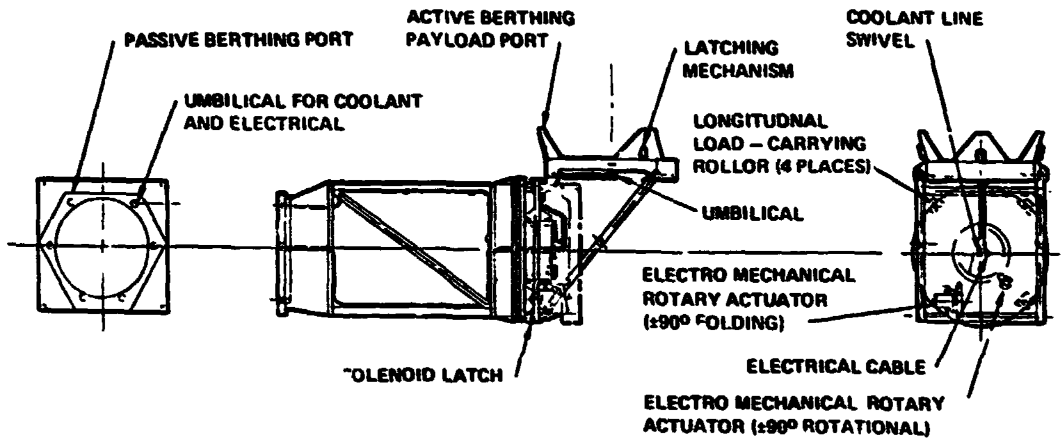
The 1st Order ncept has three identical structural configuration arms except for the rotational indexing features. The +X and -Y rotates CW and the +Y arm rotates CCW looking outboard from the Power System. Four concepts were evaluated in Task 4 and Concept "4" with automatic control of four positions was selected because it will allow the maximum viewing capability.

Figure 5.3.2-1 illustrates the mechanism necessary to provide payload multi-viewing capability. The folding feature is actuated by an electromechanical two-position rotary actuator. The rotating features are actuated by an electro-mechanical three-position rotary actuator. Solenoid latches are provided maintaining the active berthing port in the stowed position. Electrical cablings are flexed across hinges and rotating joints without slip rings. The coolant lines are flexed across the folding joints and utilizes swivel across the ±180° rotating joint. Longitudinal loads are transferred across the rotating joints in line with the main longeron to minimize the eccentric load path.

5.3.3 Second Order Platform Payload Berthing Structure and Mechanism

5.3.3.1 Second Order Platform Requirements

The basic requirements for the platform arms are to provide a stable berthing platform which will provide services such as rotation, electrical power, data, thermal control, cryogen, and multipayload berthing capability. It shall also provide locations for packaging of the electronics and thermal control systems.



- **Multiviewing Capability**
- **Coolant Line Swiveled Across ±90° Rotating Joint**
- **PAM Type Actuator for Rotating and Folding Joint**
- **Electrical Services Flexed Across Moving Joints**
- **Configuration Identical for Three Arms on First Order Except for Direction of Rotation**

Figure 5.3.2-1 First-Order Platform Payload Be:thing Structure and Mechanism

The SASP shall be designed to maintain the thermal distortions, free play and other disturbances generated by the general housekeeping systems to a minimum. The goal was to maintain the pointing accuracy to 2° and the pointing stability 6 arc min.

5.3.3.2 <u>Second Order Concept Design</u>

The initial design concept efforts addressed candidate deployable arm structures of the types shown in Figure 5.3.3-1. A preliminary estimate of the various parameters was studied.

The various types were reviewed based on the concept selection criteria developed in the study. Each of the concepts was reviewed for their features. A key requirement is the ability to compact the structure for maximum volume utilization. It is al mportant to consider the maximum reliability and minimum buildup time and checkout.

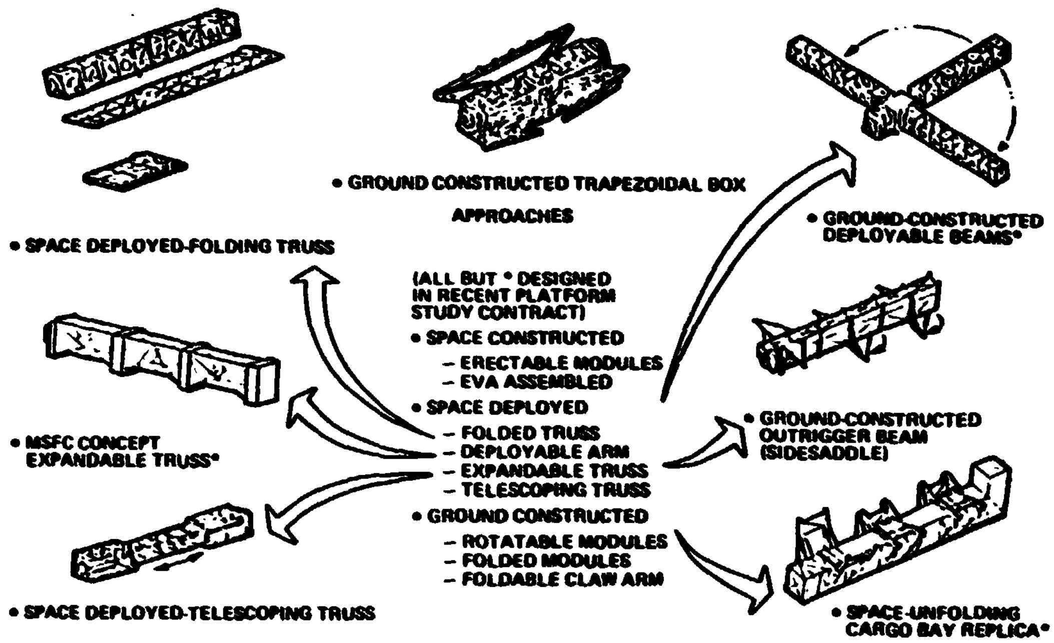


Figure 5.3.3-1 MDAC Structural Buildup Concepts Plus MSFC's = Broad Starting Base

The basic concepts reviewed were expandable, fixed, telescopic, and folding. The comparative prospects of compaction ratios and the Orbiter volume utilization were studied.

Figure 5.3.3-2 illustrates an expandable arm option with a compaction ratio of approximately 6:1. This concept is noted as the sector drive expandable. It can also be built to a larger section and assembled in orbit.

As the study proceeded, many other SASP configurations were reviewed, for example, Figure 5.3.3-3 which illustrates a concept that utilizes the telefold expandable structure requiring assembly of major sections in orbit. The stowed configuration of this truss is shown in Figure 5.3.3-4 which shows the high compaction ratio of this concept.

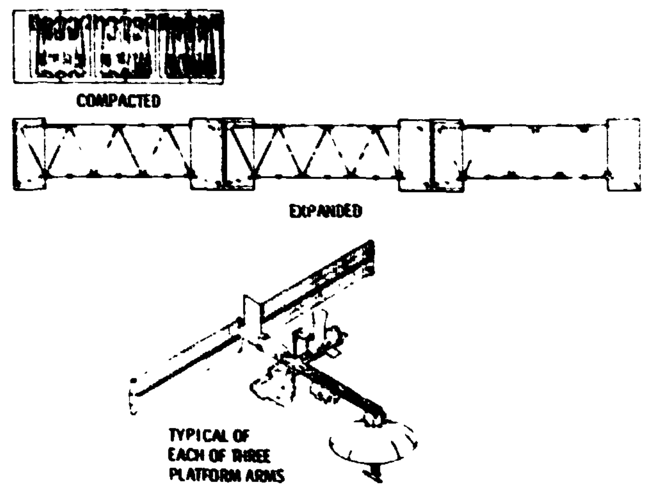


Figure 5.3.3-2 Platform Arm - Expandable Option

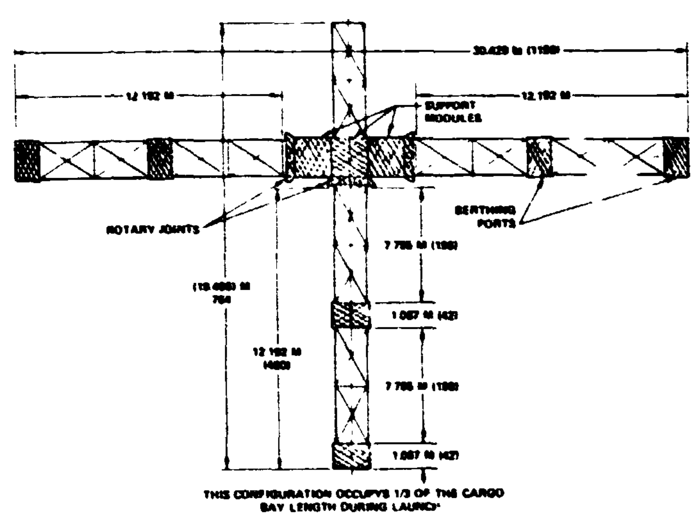


Figure 5.3.3-3 SASP Deployed Geometry

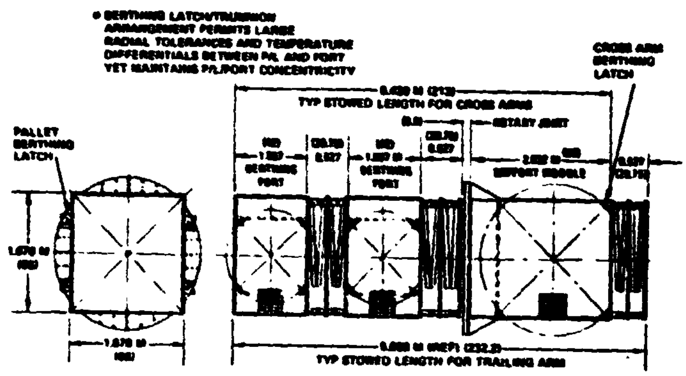


Figure 5.3.3-4a SASP Stowed Geometry

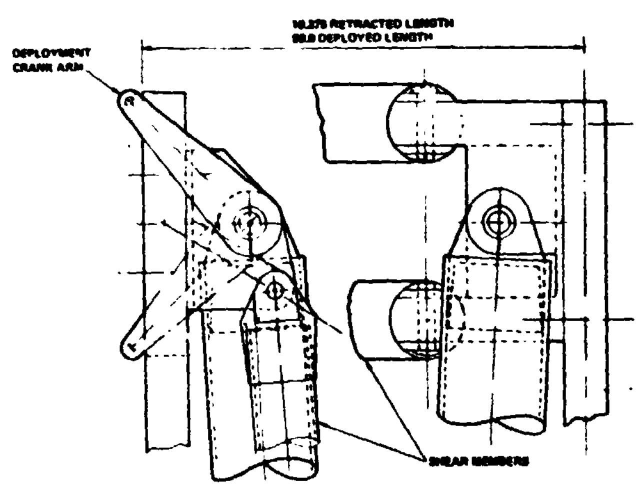


Figure 5.3.3-4b Folding Truss Retracted Geometry

The configuration for each of the cross-arms is identical to that for the center arm except for the elimination of two bays of deployable truss which are located between the Power System and the center arm. This launch configuration for the power platform uses less than 1/3 the length of the cargo bay, leaving 2/3 of the bay available for payloads for inclusion on the initial platform launch.

The gussets which backup the rotary joint frame are shown in the end and side views. The latch/trunnion arrangement for berthing the cross-arms on the center arm is identical to that proposed by MDAC for berthing payloads to the Platform.

Figures 5.3.3-5, 6, 7, and 8 illustrate the details of this folding truss concept. The truss concept was carefully layed out to eliminate any eccentricity. The graphite epoxy longerons fold between frames like the legs of a card table and the shear members are telescoping. Deployment is achieved through four crank arms located on the longeron pivot axis at one end. Each crank arm is connected via a 3/32 diameter cable and a single pulley to a center drum which drives the four crank arms synchronously. A second 3/32 cable which passes from a flexure latch opposite the central hinge on each longeron over three pulleys to the same center drum, is used for unlatching and retraction of the truss so that both deployment and retraction and accomplished with a single motor driven screw jack actuator which can also be manually driven in an EVA backup mode. Retraction is initiated via cable tension on a link opposite the strut side which has the pivot.

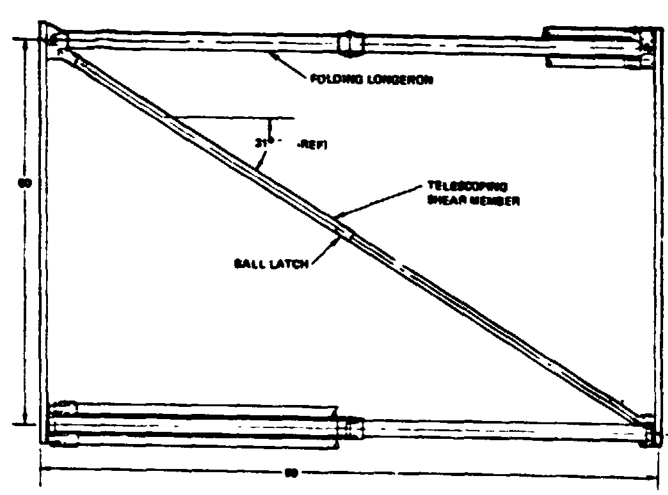


Figure 5.3.3-5 Folding Truss Deployable Geometry

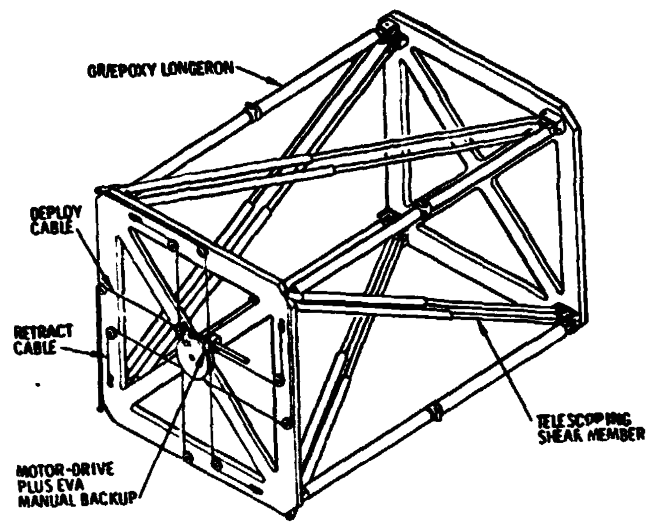


Figure 5.3.3-6 Deployable Truss

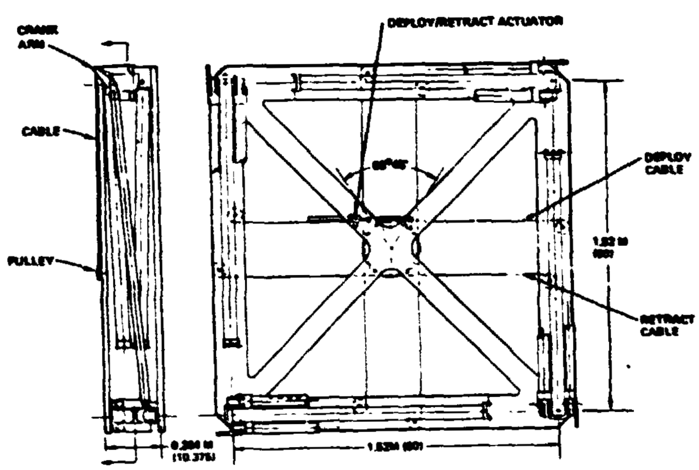


Figure 5.3.3-7 Foldable Truss

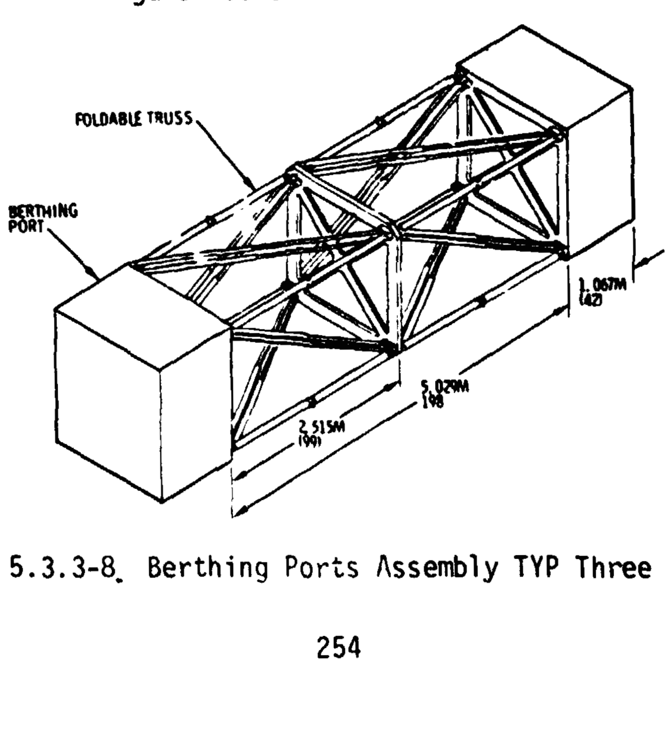


Figure 5.3.3-8 Berthing Ports Assembly TYP Three Places

5.3.3.3 Swinging Cross-arm Concept

Figure 5.3.3-9 shows the initial concept of the swinging cross-arm concept and its related service options. The swing arm concept shown has many advantages, some of which are: (1) complete checkout on the ground, (2) minimal buildup time, (3) no EVA, and (4) total auto deployment. The arms are folded during launch and restrained by integral support structures. A rotating joint is utilized to allow 360° rotation of the arm for pointing and ease of accessibility during loading and unloading and maintenance. The actuation mechanism will be designed for quick changeout in case of failure.

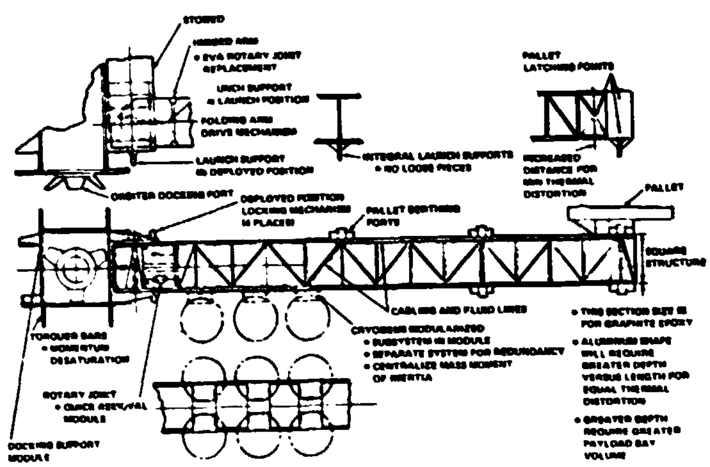


Figure 5.3.3-9 Detail of Folding Platform Arm

Each arm has multiple pallet berthing ports and is spaced for ease of replacement and for minimizing viewing obscuration of adjacent pallets. The berthing ports will be designed to preclude binding due to thermal distortion. This arm shows a special case where cryogen is berthed to support certain experiments. A conceptual sketch of the latest folding joint is shown in Figure 5.3.3-10.

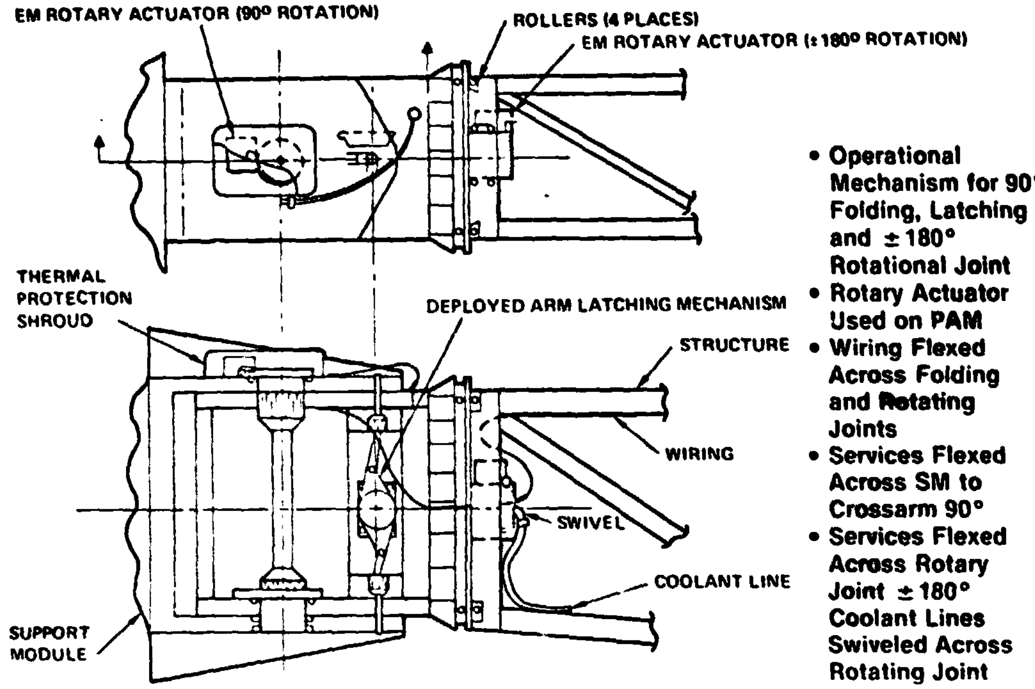


Figure 5.3.3-10 Second-Order Platform Arm Folding Joint Mechanism

The platform cross arms were designed with a folding joint to facilitate compaction for launch and arm rotation for servicing. The rotation feature on the arm is to allow payloads without a pointing system to increase its viewing capability; it may also aid an instrument pointing payload to increase its field-of-view capability. The mechanisms utilized to drive the folding and rotational joints are space-qualified type actuators. The rollers at the rotating joint carry the longitudinal loads across the rotating joint. The shear loads are transmitted across the rotational mechanism in the center. All power and data are flexed across all the moving joints except the coolant line across the $\pm 180°$ joint which is transferred by means of a swivel joint.

5.3.3.4 Extendable Arms

Various studies were conducted on the growth options on the 2nd Order Extended Concept which were shown earlier. Figure 5.3.3-11 shows the general construction of the deployable cross arm extension in its deployed and retracted position.

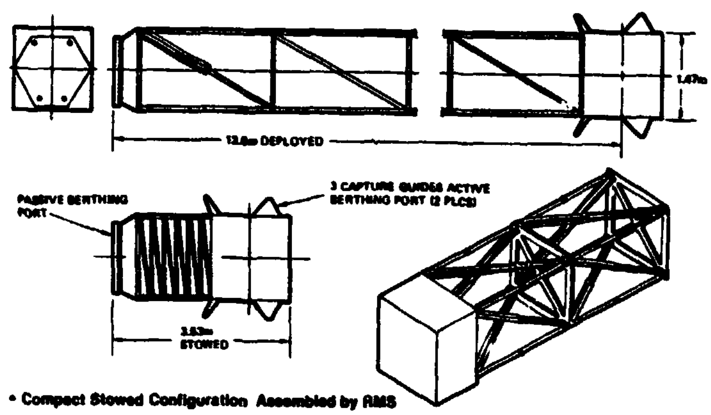


Figure 5.3.3-11 Left and Right Arm Extension (Extended Second-Order Platform)

This arm is a means of providing additional capability for payloads as the program expands. This arm has two active berthing ports for payload mounting and the truss is expandable. The compaction ratio is approximately 10 to 1. This arm requires assembly in orbit with the RMS. One end of the arm has a passive berthing port which also houses the umbilicals. This arm can be fully checked out on the ground. The other feature is that the arm may be retracted when not in use.

The trail arm growth option for the Second Order Extended Concept provides additional viewing capability (see Figure 5.3.3-12). The trail arm provides 360° rotational capability necessary for certain experiments. This section of structure provides location for mounting of the radiator. This design will require no coolant to be transferred across the rotary joint. Two active berthing ports are provided for the payload interface. A passive port is utilized to interface with the Support Module on the SASP. Power and data are transmitted across the 360° joint by means of roll rings. The basic structural configuration is identical to the extension structure between the Power System and the Support Module on the SASP, except for the berthing ports.

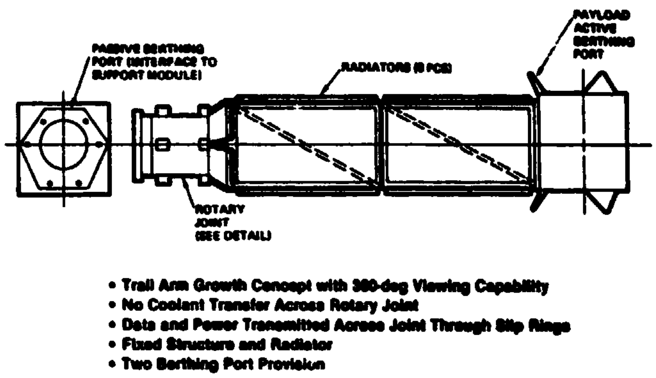


Figure 5.3.3-12 Trail Arm Fixed Truss With 360-Deg Rotary Joint

5.3.3.5 Orbiter to SASP Berthing

Figure 5.3.3-13a shows the Orbiter berthing units required for the 1st and 2nd Order Platforms if the single regular RMS is used. Figure 5.3.3-13b shows the requisite features of the 2nd Order Platform telescoping boom and two design options recommended for the follow-on study. The initial design concept was the preliminary concept to satisfy the requirement of servicing the SASP with the Orbiter limited to a single berthing/rendezvous. Further study of the servicing sequence indicated that the boom had to telescope for enough to reach the Power System propulsion replacement while being berthed to the Support Module on the SASP. The stiffness requirement could not be met with the initial concept. The telescoping boom is a permanent part of the SASP and is stowed under the extension during launch. It provides all of the necessary rotational features to satisfy all of the servicing requirements of the SASP and Power System. The passive Orbiter interface is identical to all of the passive ports on the SASP, pallets and Power System. This system should be pursued further when all the different payload flight scenarios are determined.

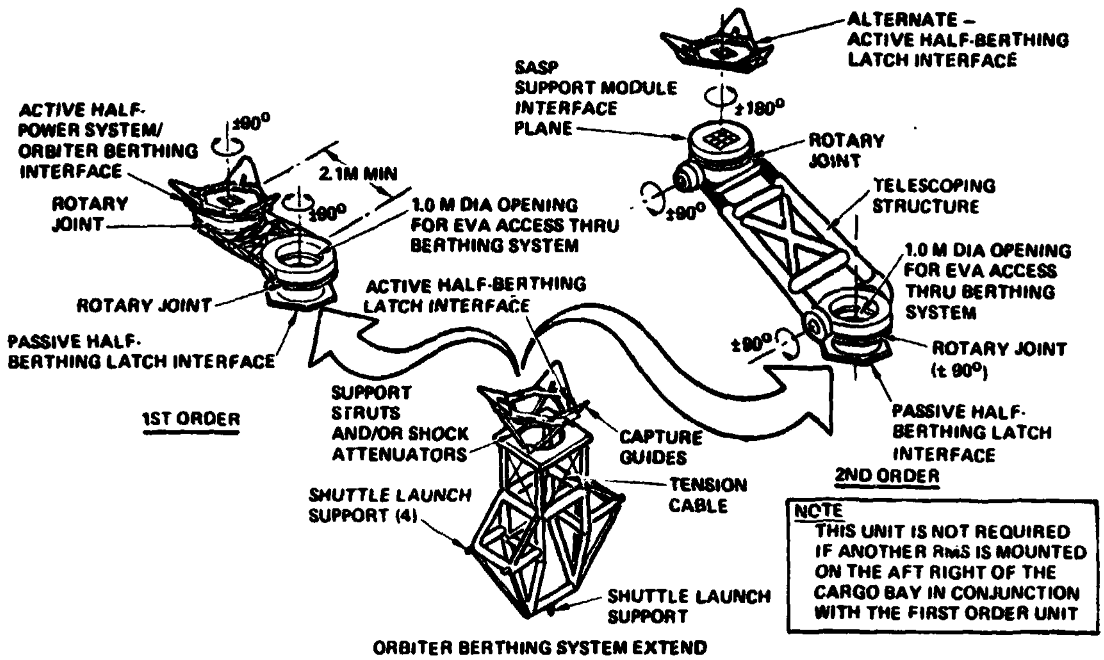


Figure 5.3.3-13a SASP Berthing System

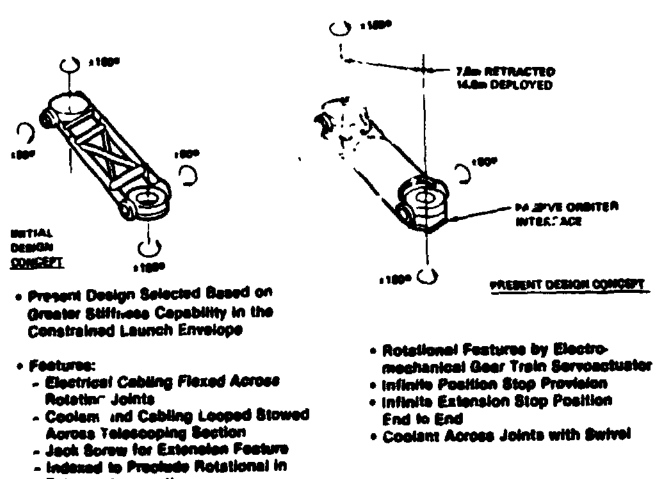


Figure 5.3.3-13b Telescoping Boom for Orbiter Berthing and Loading Aid

5.3.4 Mechanism Summary (1st and 2nd Order Platform)

The basic function, type, quantity, and features of the platform mechanisms are shown in Table 5.3.4-1. The goal was to utilize the same or similar components where possible to maintain low development and testing costs. Flight proven and qualified components from other space programs were considered. It may be necessary to modify certain features of the existing hardware to meet certain requirements. The type of components selected was greatly influenced by the availability of electrical power, weight, and reliability of electrical mechanical components.

Item	Function	Mechanism	Qty 1st	Qty 2nd	Manual Backup	Jettison Required	Redundant	Config 1st	Config 2nd
1	Berthing Port Umbilical	Electromechanical Gear Train Rotary Actuator (1/BP Elect, 1/BP Coolant)	6	11	Yes	Yes	Yes	✓	✓
2	Berthing Port Latch	Electromechanical Gear Train Rotary Actuator and Electro-mechanical Solenoid	6	11	Yes	No	Yes	✓	✓
3	±90° Rotary Joint	Electromechanical Gear Train Rotary Actuator	3		Yes	No	Yes	✓	
4	90° Hinge Payload Deployment	Electromechanical Gear Train Rotary Actuator	3		Yes	No	Yes	✓	
5	90° Hinge Retraction Latch	Electromechanical Solenoid Linear	3		Yes	No	Yes	✓	
6	±180° Rotary Joint	Electromechanical Gear Train Rotary Actuator		2	Yes	No	Yes		✓
7	Rotary Joint Stowed Position Latch	Electromechanical Gear Train Two-Position Linear Actuator		2	Yes	No	Yes		✓
8	Arm Folding Joint Deployment	Electromechanical Gear Train Rotary Actuator		2	Yes	No	Yes		✓
9	Deployed Position Folding Joint Latch	Electromechanical Gear Train Two-Position Linear Actuator		4	Yes	No	Yes		✓
10	Arm Stowed Position Launch Restraint Latch	Electromechanical Gear Train Two-Position Linear Actuator		4	Yes	No	Yes		✓
11	Telescoping Boom Yaw Rotational	Electromechanical Gear Train Rotary Actuator		2	Yes	Yes	Yes		✓
12	Telescoping Boom Pitch	Electromechanical Gear Train Rotary Actuator		2	Yes	No	Yes		✓
13	Telescoping Boom Extension	Electromechanical Gear Train Jack Screw Linear		1	Yes	No	Yes		✓
14	Rotary Joint Drive	Electromechanical Gear Train Rotary Actuator		1	Yes	No	Yes		✓
15	Growth Cross Arm Telefold Deployment	Electromechanical Gear Train Rotary Actuator (Drum)		12	Yes	No	Yes		✓

Table 5.3.4-1 First and Second Order Platform Mechanism Summary

C-4

5.4 STRUCTURES AND MATERIALS ANALYSIS

The following work was accomplished in this task.

- Minimum structural frequency established as .1 Hz from overall attitude control considerations.
- Preliminary investigation indicates pointing systems may impose a structural requirement on SASP; further study required.
- Structural temperature and temperature gradient extremes predicted for:
  - graphite/epoxy cross-arm (inertial orientation).
  - insulated aluminum cross-arm (inertial orientation).
  - graphite/epoxy trail arm (earth orientation).
  - stand-off structure radiator panels (inertial orientation).
- Potential application of insulated aluminum structure in selected areas indicated; further study required.
- Structural dynamics model established:
  - frequencies and mode shapes determined.
  - minimum structural frequency of .1 Hz is satisfied.
  - frequency and transient response analyses conducted; benefits of enhanced structural damping indicated.

The following conclusions were developed in this task.

The minimum structural frequency requirement is .1 Hz from overall attitude and control considerations.

There is some reason to believe that the experiment pointing systems may impose a requirement on the structure. This issue, which is beyond the scope of this study, needs to be studied and resolved in a timely manner.

Structurel temperature predictions for a graphite/epoxy structure indicate a T max = 163°F, T min = -127°F and longeron to longeron ΔT AVG MAX = 205°F.

Temperature predictions for an insulated aluminum cross arm in inertial orientation at β = 52° indicate a ΔT AVG MAX = 104°F and is essentially constant throughout the orbit. This concept should be studied further as an alternative to graphite/epoxy for the cross-arm structure.

Structural distortion temperature gradients of the stand-off structure surrounded by radiator panels should be less than 138°F. An insulated aluminum stand-off truss along with an uninsulated aluminum stand-off truss that considers the addition of sensors to the Support Module as a new attitude reference point should be evaluated.

A NASTRAN structural dynamics model of the 2nd Order Extended SASP indicates the minimum structural frequency of .1 Hz is satisfied.

Frequency and transient response analyses indicate that implementing methods of enhanced structural damping can be of significant benefit to SASP.

5.4.1 Minimum Structural Frequency Required for Overall Attitude Control

Referring to Figure 4.2.8-1 under trade studies of the controls section, it can be seen that the maximum frequency of the control region frequency band is .01 Hz. Using the rule of thumb factor of 10 separation between the maximum control frequency and the minimum structural frequency, the minimum structural frequency requirement becomes .1 Hz as noted on the figure.

5.4.2 Potential Requirement Imposed on SASP by Pointing Systems

The minimum structural frequency requirement of $f_n \geq .1$ Hz established in Subsection 4.2.8 is based upon overall altitude control considerations. It is possible that the pointing system line-of-sight (LOS) stability requirements will impose a requirement on the structure. Additional analysis, beyond the scope of this study, will be required to determine the significance of this potential requirement. Preliminary discussions with Spacelab integration systems engineers indicate the Spacelab pallet and Orbiter support structure has a minimum structural frequency $f_1 = 4$ Hz. Hence, it would seem reasonable to conclude that a 4 Hz structure would be a fundamental frequency upper limit requirement in order to provide minimum impact to the pointing systems now being developed. Recognizing that loading disturbance inputs and structural response on Spacelab are probably quite different and could be more severe than on SASP, it is very possible that structural frequencies less than 4 Hz will be acceptable.

It was considered of interest to determine what impact a 4 Hz structure would have on SASP. Figure 5.4.2-1 shows the structural geometry required for a 4 Hz 54 in x 54 in by 384 long graphite/epoxy cantilever arm. Geometries are shown for a truss structure and monocoque box structure. It can be seen

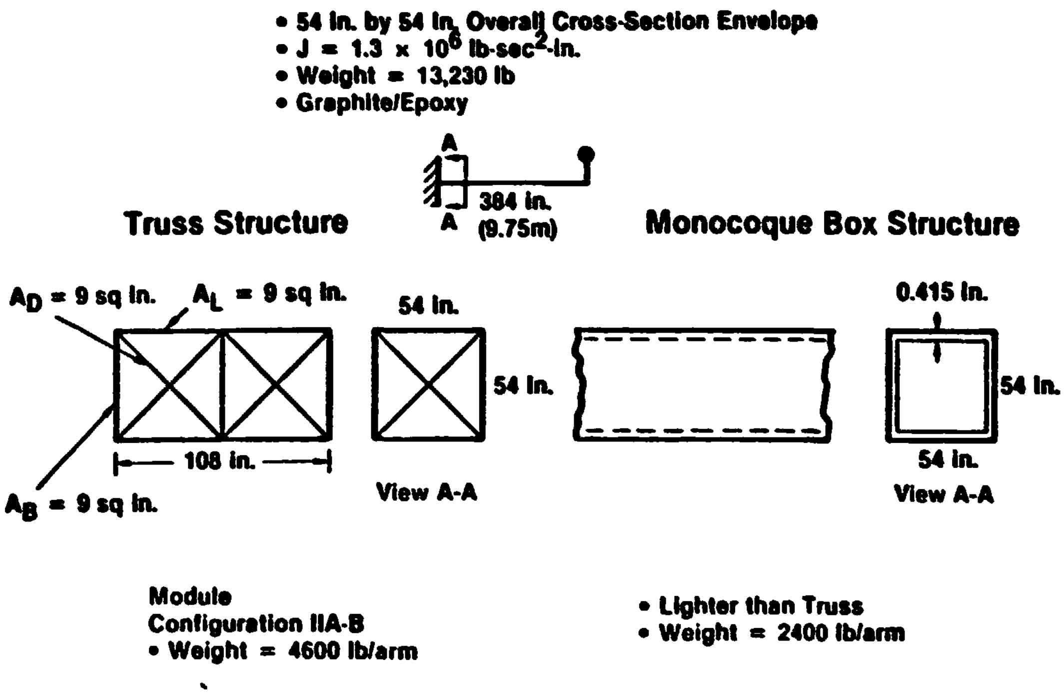


Figure 5.4.2-1 ~4 Hz Cantilever Arm Structure

that the monocoque box structure is lighter than the truss for this case. Additionally, the 4 Hz monocoque box is substantially heavier than the .1 Hz truss structure, but is still viable as a deployable folding arm SASP structure.

In summary, it is concluded that a f = .1 Hz structure:

(a) satisfies overall attitude control requirements.

(b) can be provided with low structures technology.

(c) requires additional analysis, beyond scope of this study to determire pointing system LOS stability error.

f = 4 Hz structure:

(a) represents an upper limit on fundamental frequency requirement.

(b) is heavier but still viable.

(c) minimizes control development.

(d) places inordinate burden on structure.

For the purpose of this study, a .1 Hz will be considered the minimum frequency requirement until additional analysis, which is beyond the scope of this study, is conducted to understand the potential requirement that the pointing systems may impose on SASP.

5.4.3 Structural Temperature Predictions

The predicted structural orbital temperature history for the SASP graphite/epoxy cross arm longerons is shown on Figure 5.4.3-1. The predictions are based upon an inertial orientation. The angle \ is considered to remain constant for a given revolution.

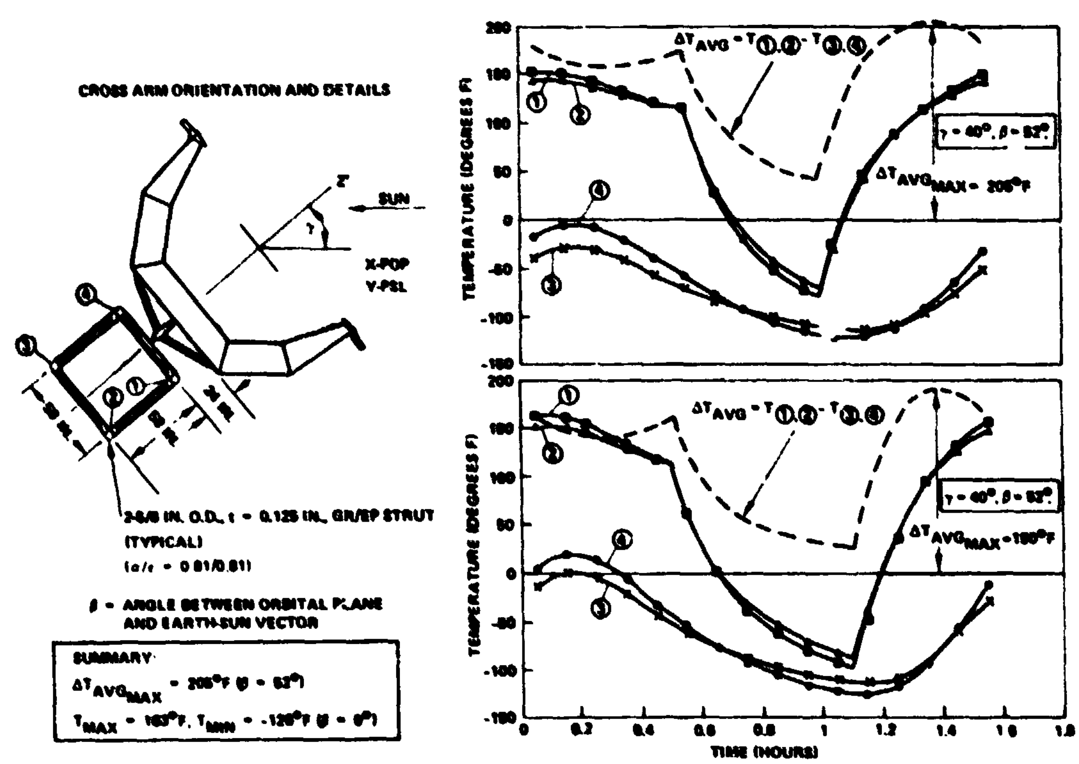


Figure 5.4 3-1 Graphite/Epoxy Cross Arm Structural Orbital Temperature History (Inertial, Orientation, Altitude = 435 km)

For the $\beta = 0°$ case, the maximum longeron to longeron ΔT_{max} = T(1),(2)AVG-(T)(3),(4) AVG is predicted to be 190°F. The maximum temperature excursion for longeron (1) ranges from T_{max} = 163°F to T_{min} = -99°F. The minimum longeron temperature of any longeron is -126°F for longeron (4).

For the $\beta = 52°$ case, the maximum longeron to longeron ΔT_{max} = T(1),(2)AVG-T(3),(4) AVG is predicted to be 205°F. The maximum temperature excursion for longeron (1) ranges from T_{max} = 153°F to T_{min} = -78°F. The minimum longeron temperature for any longeron is -121°F for longeron (4).

It was considered of interest to predict the structural orbital temperature history for a SASP cross arm truss structure consisting of aluminum struts wrapped with MLI. The results are shown on Figure 5.4.3-2 for an inertial orientation. Temperatures for this case can be compared directly to those predicted previously for a graphite/epoxy structure for $\beta = 52°$.

It can be seen that the maximum longeron to longeron $T_{AVG\ MAX}$ is 104°F and is essentially constant throughout the orbit. This indicates that this concept potentially offers an alternative to graphite/epoxy for the fixed truss structure since, although the structural gradient is relatively large, it is essentially constant. For this case, the quasi-static thermal distortions could be compensated for by the overall attitude control system. Thermally induced dynamic response would be negligible. This approach however, could place some restrictions on the simultaneous viewing of payloads without pointing system since the attitude compensation could only be accomplished for one payload at a time. Application of this concept needs further evaluation with respect to manufacturing installation, joint wrapping and use on a deployable arm.

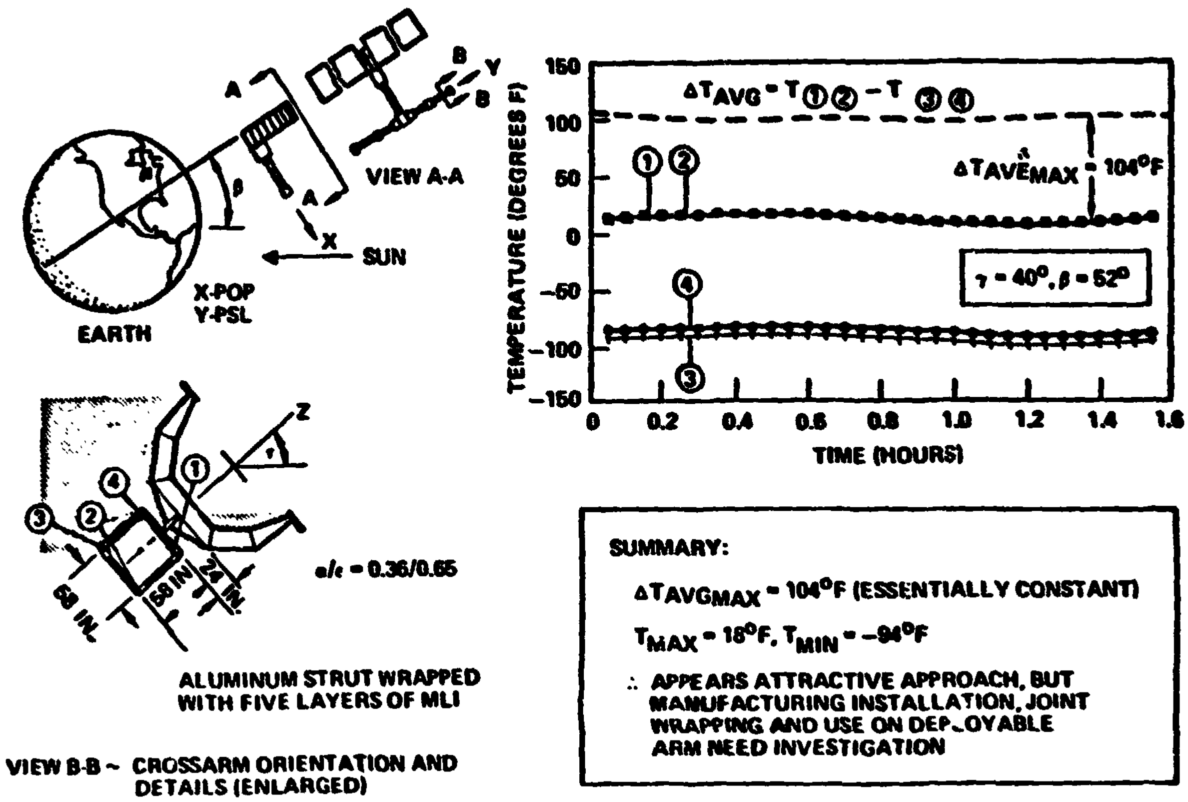


Figure 5.4.3-2 Insulated Aluminum Cross Arm Structural Orbital Temperature History (Inertial Orientation, Altitude = 435 km)

The predicted structural orbital temperature history for the SASP graphite/epoxy trail arm longerons is shown on Figure 5.4.3-3. The predictions are based upon an earth orientation Z-LV, Y-POP, X-VV for β angles of 2.5° and 30°. For the $\beta = 2.5°$ solution, the temperature excursion of longerons (1) and (4) ranges from $T_{max} = 142°F$ to $T_{min} = -127°F$. The ΔT between longerons (1), (4) and (2), (3) varies to maximum extremes of $\pm 43°F$.

For the $\beta = 30°$ solution, the temperature excursion of longerons (1) and (4) ranges from $T_{max} = 163°F$ to $T_{min} = -115°F$. The ΔT between longerons (1), (4) and (2), (3) varies from a maximum positive value of 37°F to an average maximum negative value of -50°F.

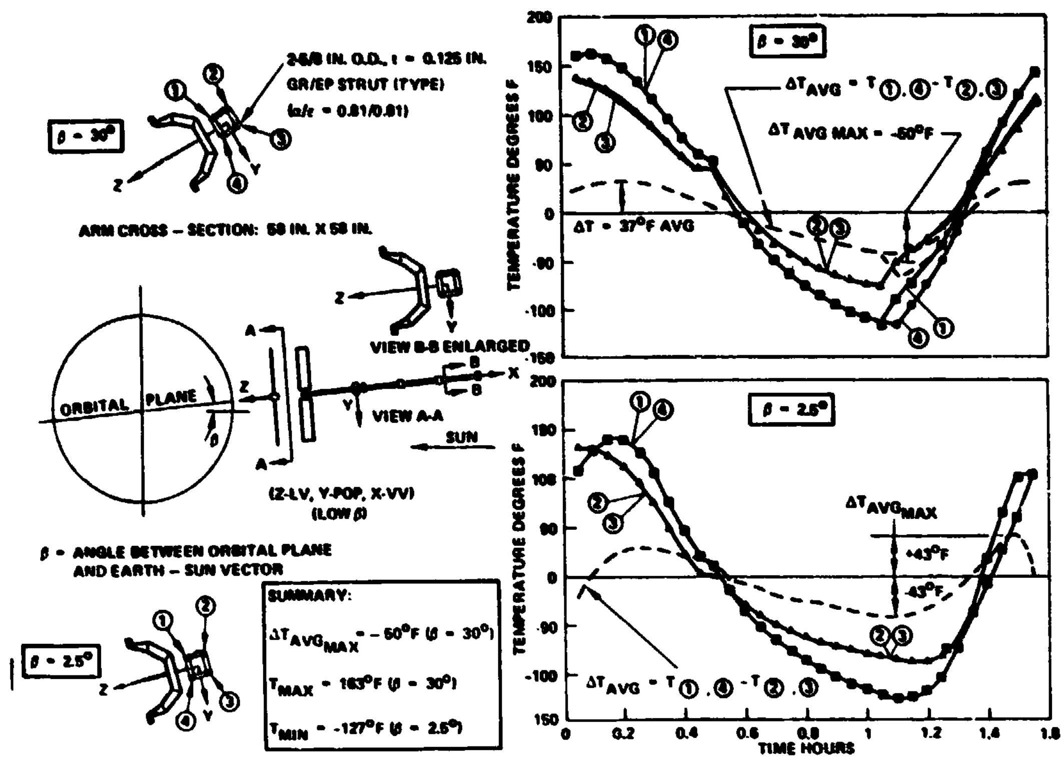


Figure 5.4.3-3 Graphite/Epoxy Trail Arm Structural Orbital Temperature History (Earth Orientation)

These data are considered to be representative of the structural temperatures for low β angles with the exception of the range β<2.5°. As β approaches zero, longerons (2), (3) shadow longerons (1), (4) with full shadowing occurring at β=0. For this case the longeron to longeron ΔT's will be somewhat greater than show.

Temperatures were also predicted for the radiator panels that surround the stand-off arm in order to define the local temperature environment of the stand-off arm structure and assess the structural thermal gradient potential The results of this analysis are shown on Figure 5.4.3-4. The analysis considers the flow pattern shown for panels 3 and 4 with the control temperature being maintained at 60°F.

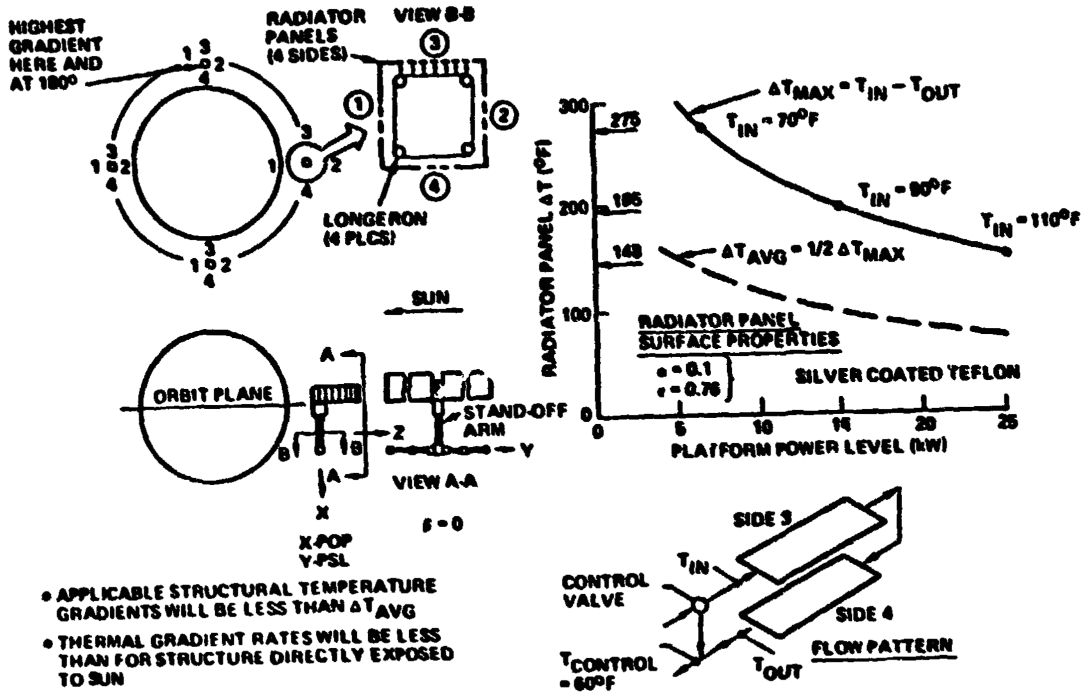


Figure 5.4.3-4 Stand-off Arm Radiator Panel Temperature Environment (Inertial Orientation)

It is seen that the results vary with platform power level. The maximum radiator panel temperature of 110°F and minimum thermal gradient (148°F) occur at maximum power level (maximum flow rate) whereas the minimum peak temperature (70°F) and maximum thermal gradient (275°F) occur for minimum platform power levels. For a 5 kW power level, the lowest radiator panel temperature is -205°F.

The structural temperature gradients that contribute to platform thermal distortion will be more nearly proportional to half the maximum radiator temperature gradient. Hence, the maximum structural temperature gradient will be less than 138°F and the thermal gradient rate will be less than for structure directly exposed to the sun.

5.4.4 Structural Dynamics Analysis

Figure 5.4.4-1 shows the NASTRAN structural model developed for the SASP 2nd Order Extended Configuration. The arm properties are based upon the truss module IB-B configuration. One solar and three celestial viewing payloads were selected as a representative mix of experiment mass and pointing require-ments. Pallet and structural mass properties were input at Modes 4, 5, 6, 7, and 8 while experiment mass properties were input at 10, 11, 12, and 13. Power Module mass was input at Mode 2 and radiator mass at Mode 105. Stand-off and cross arm element lengths are noted. The model consists of 23 grid points and 57 degrees of freedom. Solar array mast modes are included but blanket modes are not.

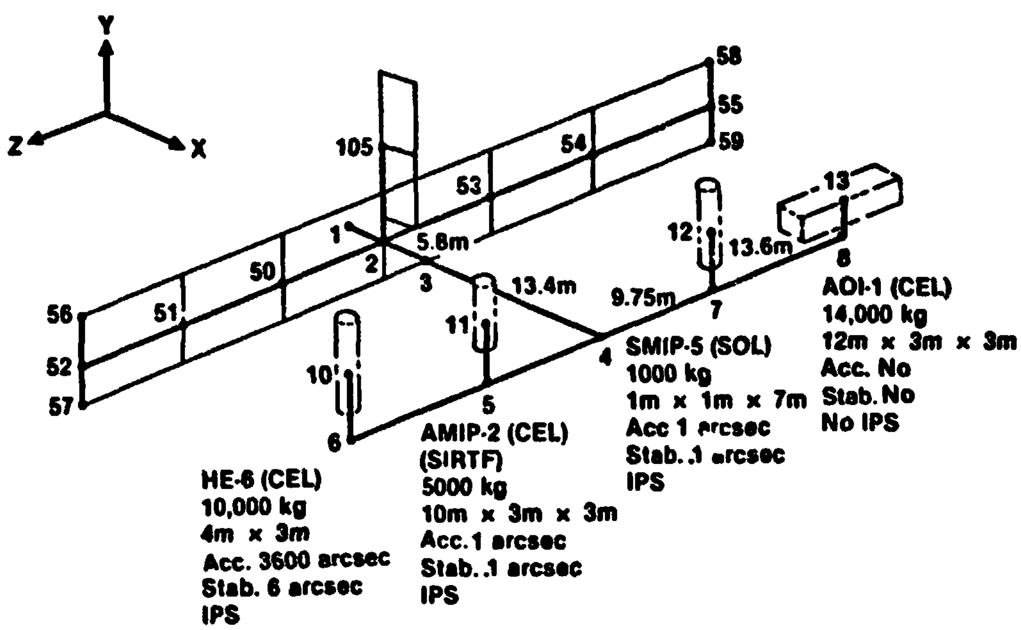


Figure 5.4.4-1 SASP NASTRAN Structural Dynamics Model

A plot of mode number vs frequency is shown as Figure 5.4.4-2 and provides an indication of the grouping and density of resonances. The slope of this plot indicates the frequency range over which the finite number of degrees of freedom in the model provide a reasonable approximation to the "real world". The reality of the model begins to break down where the slope of the plot begins to decrease. This effect is due, of course, to the finite number of parts used to represent a continuous structure. These higher order modes, however, must still be carried in any solution with substantial damping in order to achieve proper convergence (mathematically). Based on this slope change, the model is considered useful to 3 Hz. There are 22 modes below 1 Hz. As can be seen, the minimum frequency of the model is greater than .1 Hz which satisfies the minimum frequency requirement.

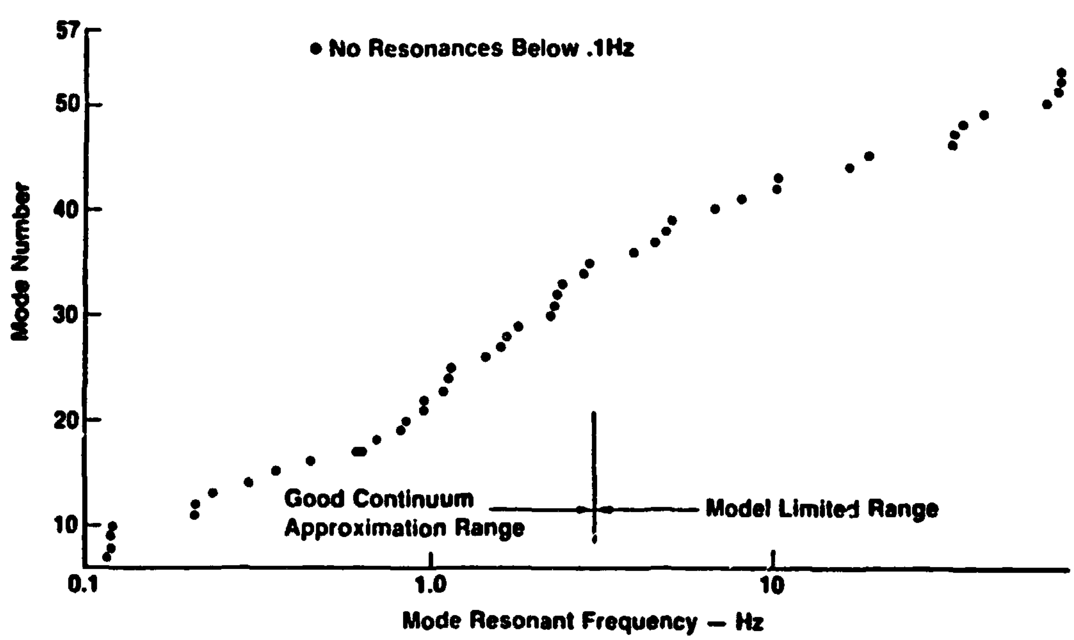


Figure 5.4.4-2 SASP Modal Density

Two selected frequencies and mode shapes are shown on Figure 5.4.4-3. The first six modes are rigid body modes. Mode 7 (.117 Hz) shows significant movement of the solar array mast with insignificant platform movement. At mode 12 (.211 Hz), platform movement begins to be significant.

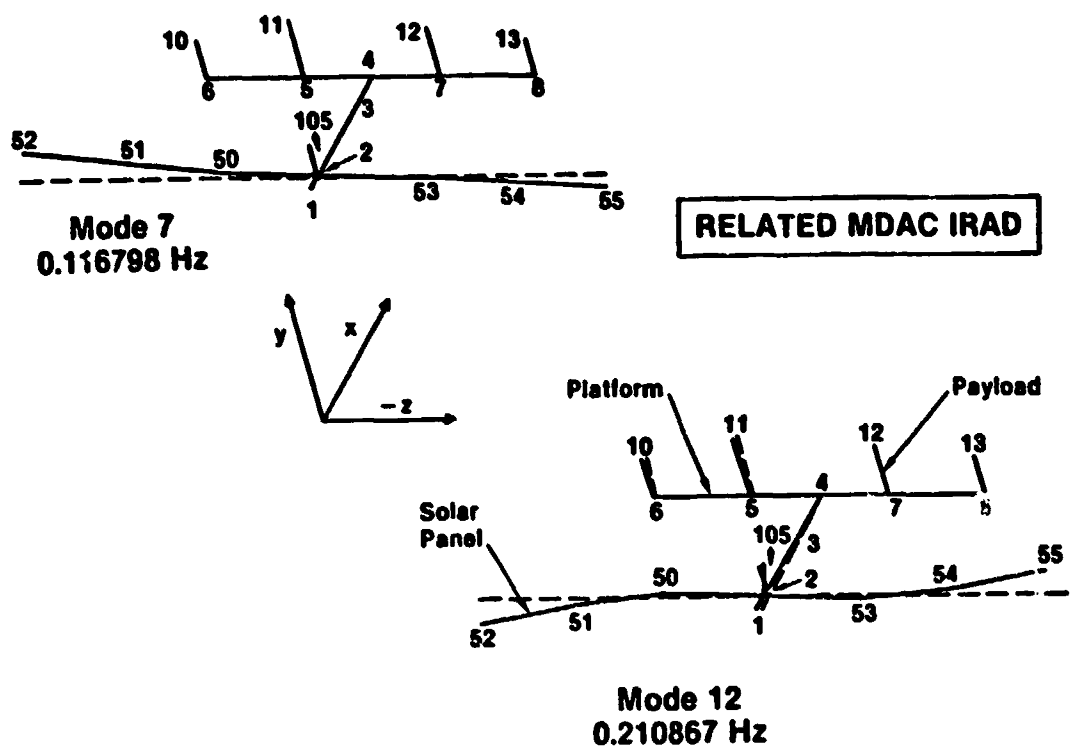


Figure 5.4.4-3 Selected Frequencies and Mode Shapes

A convenient method of implementing enhanced damping in a truss structure such as the SASP is shown on Figure 5.4.4-4 which was developed by MDAC under a DOD study contract and reported in Reference 4.8. As can be seen, substantial loss factors can be achieved by providing a minimal amount of viscoelastic material at truss member joints without great sacrifice in stiffness. This concept, if applied to the SASP, could produce a large increase in structural damping at virtually zero weight impact.

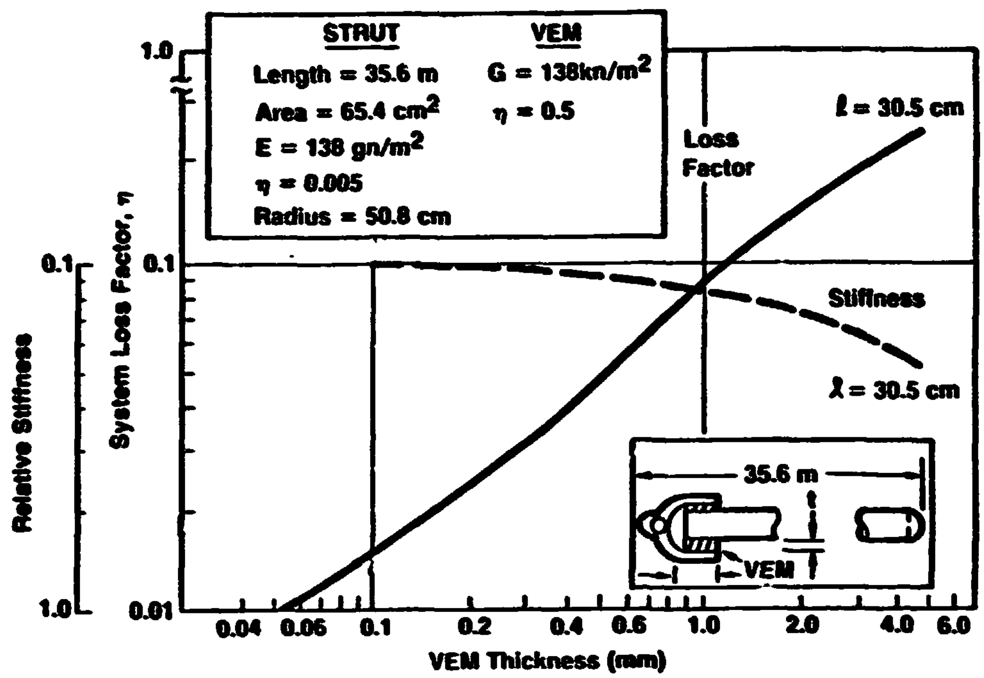
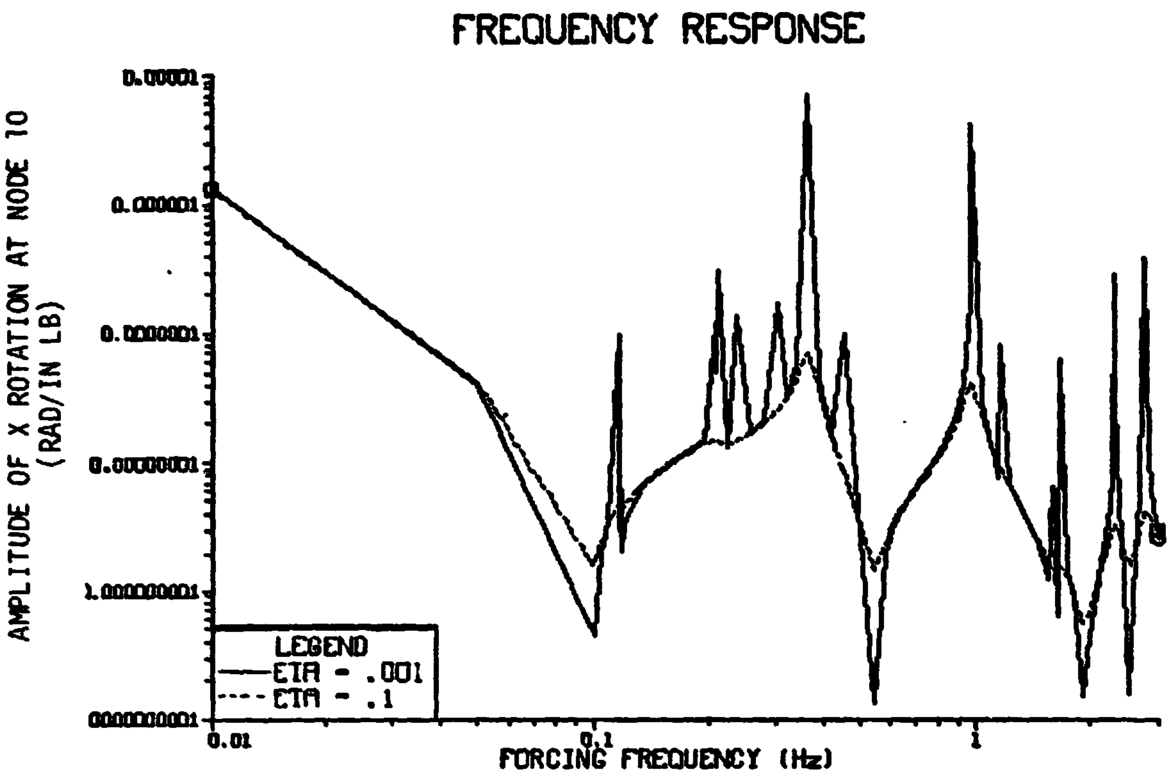


Figure 5.4.4-4 Viscoelastic Materials Effectiveness of Damping Treatment on Strut Extensional Damping (From Reference (4.8))

Figures 5.4.4-5 through 5.4.4-10 show samples of the frequency responses of the SASP which were calculated on IRAD funds. These figures characterize the effects of damping on the amplitude and phase response from a unit harmonic torque at node 10 applied in the θ_x direction. At the driving point (Figure 5.4.4-5) the lightly damped structure (η = .001) has several significant resonant peaks the largest of which could produce a response of $\pm$2000 μ radians from a $\pm$34 n-m torque at 0.4 Hz. Increasing the structural damping to η = 0.1 drops the response at the driving point to $\pm$20 μ radians. The damping also smooths out the phase changes vs frequency. Corresponding reductions in response are achieved at the other locations shown. The η = 0.1 may be obtained with only a 10% loss in structural stiffness.



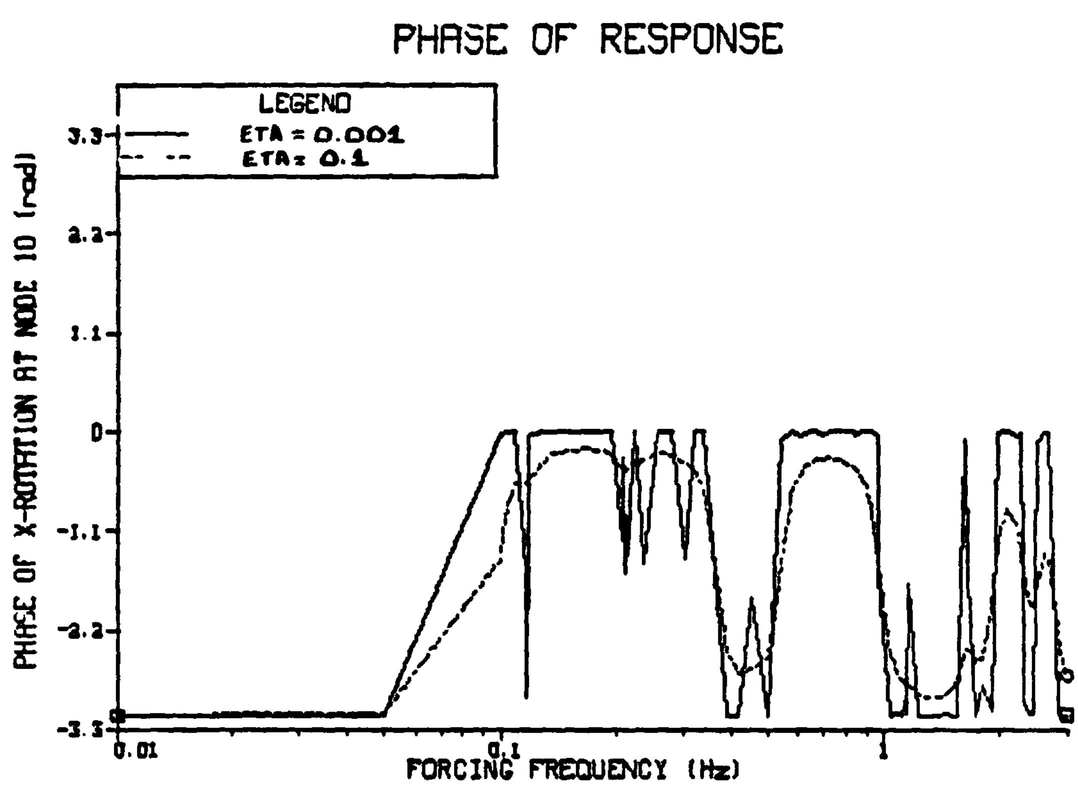


Figure 5.4.4-5 Response of Node 10 from a Unit θ Torque at Node 10

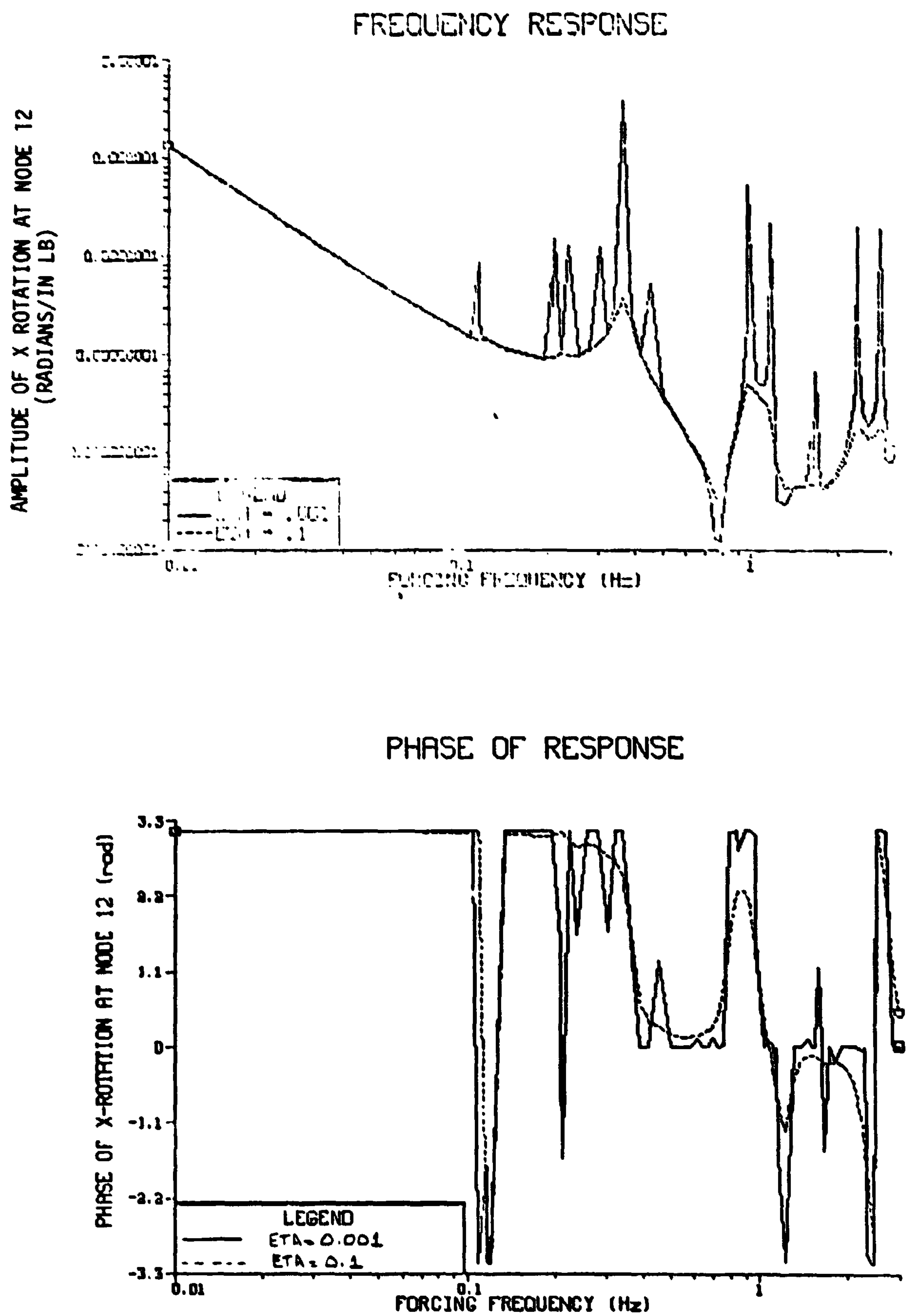
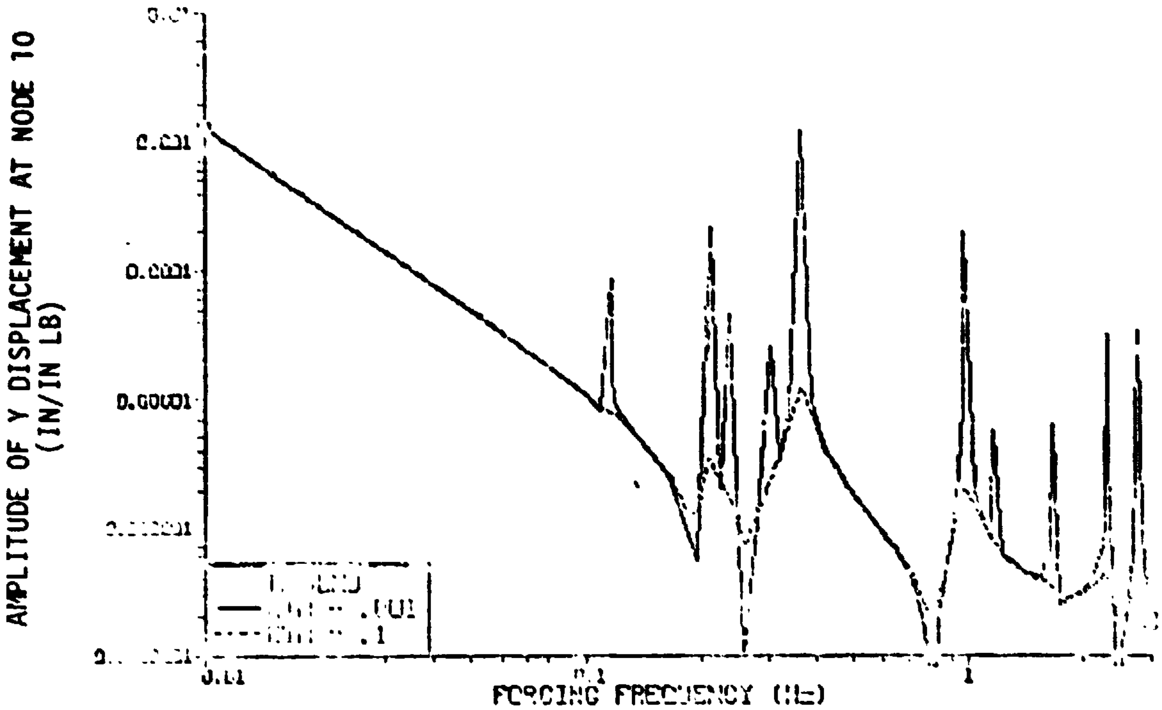


Figure 5.4.4-6 θ_x Response of Node 12 from a Unit θ_x Torque at Node 10

FREQUENCY RESPONSE



PHASE OF RESPONSE

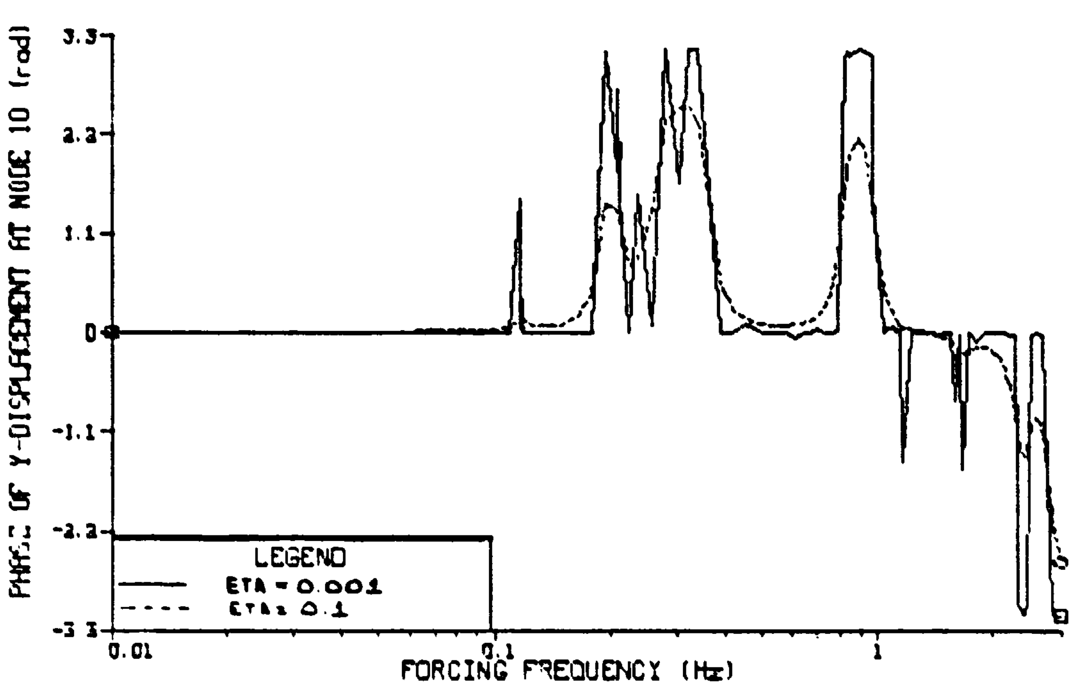
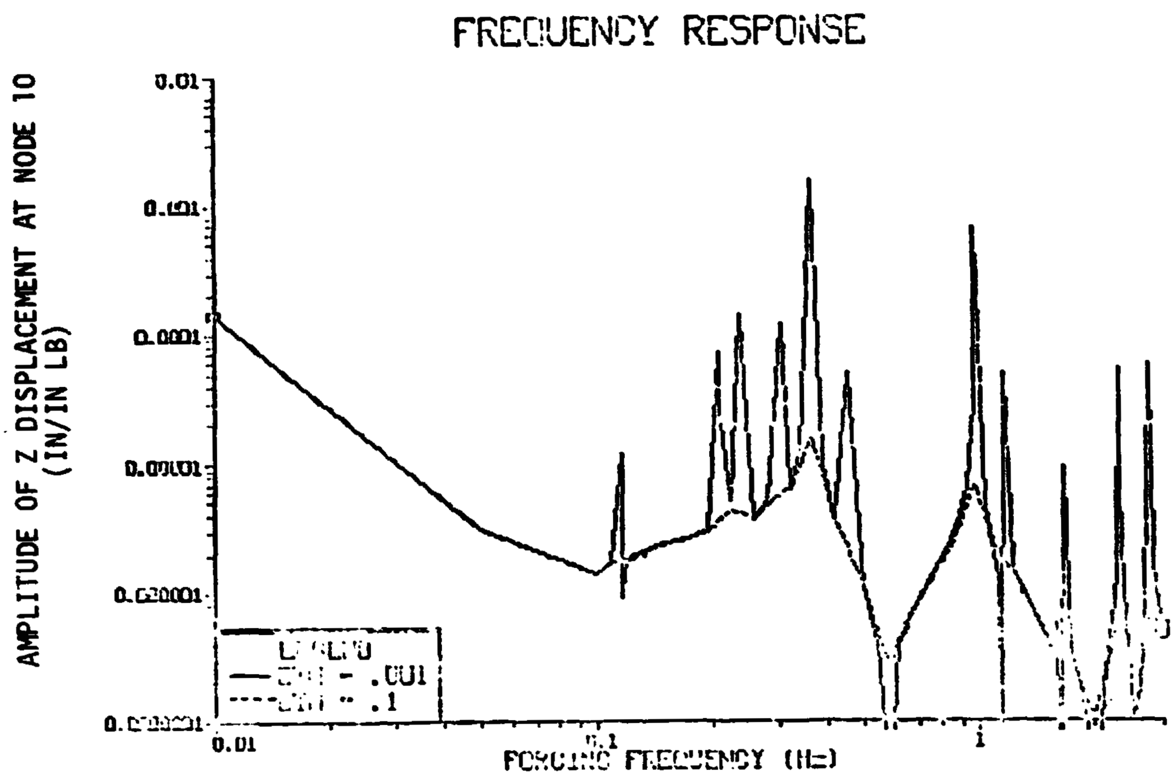


Figure 5.4.4-7 Y Response of Node 10 from a Unit θ_x Torque at Node 10



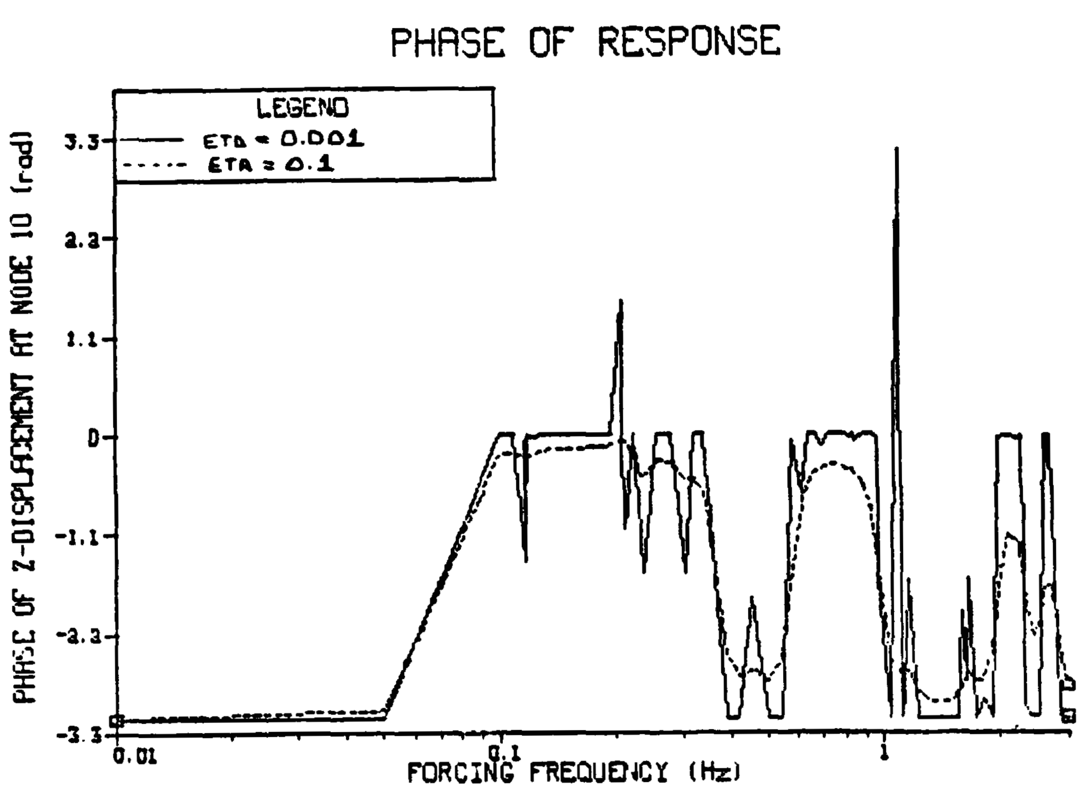
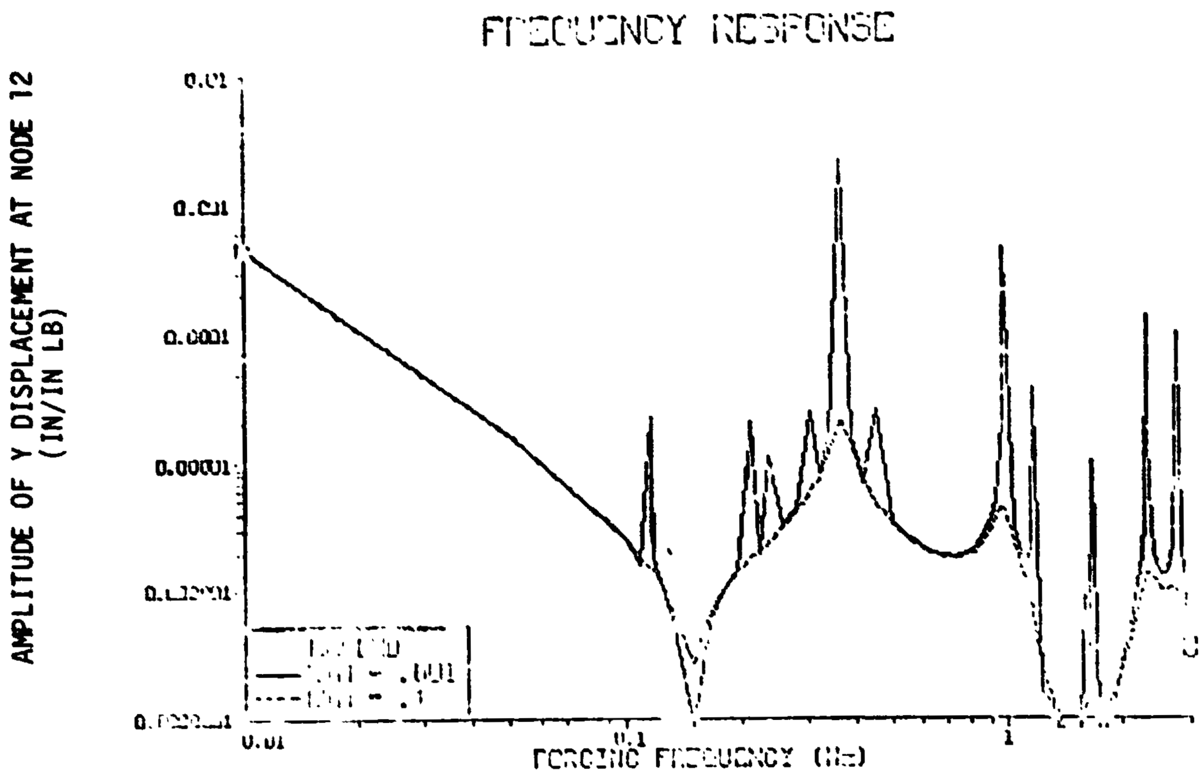


Figure 5.4.4-8 Z Response of Node 10 from a Unit θ_x Torque at Node 10



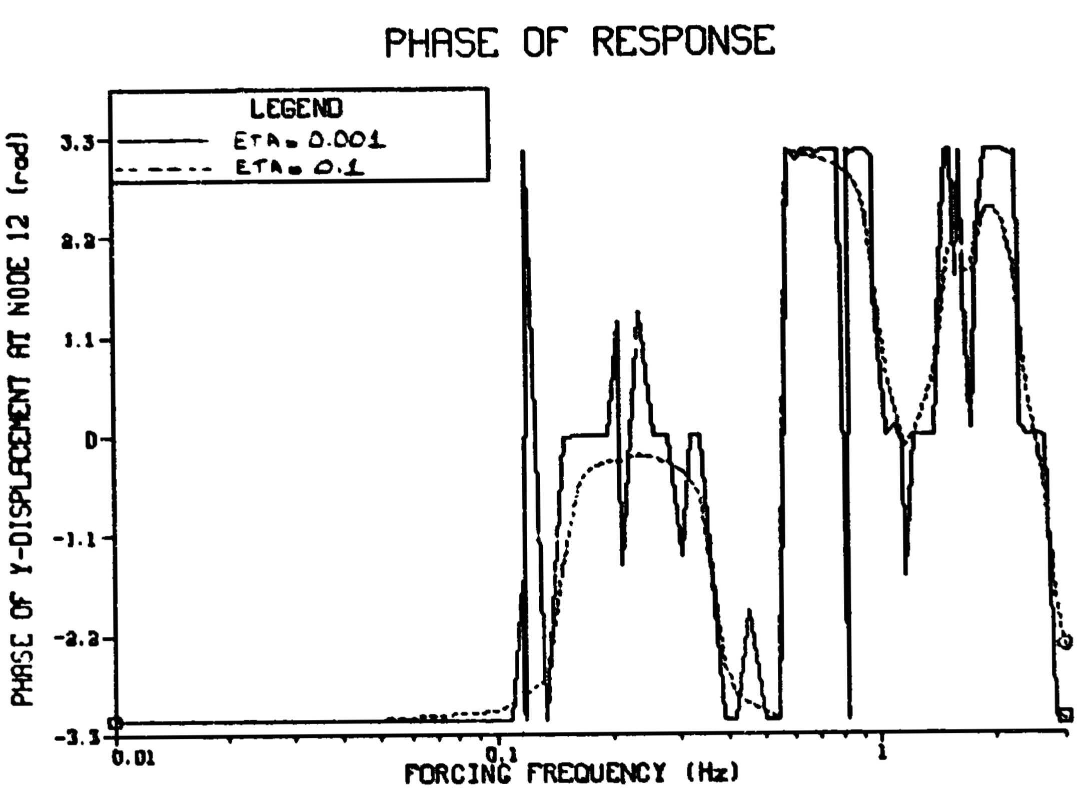


Figure 5.4.4-9 Y Response of Node 12 from a Unit θ_x Torque at Node 10

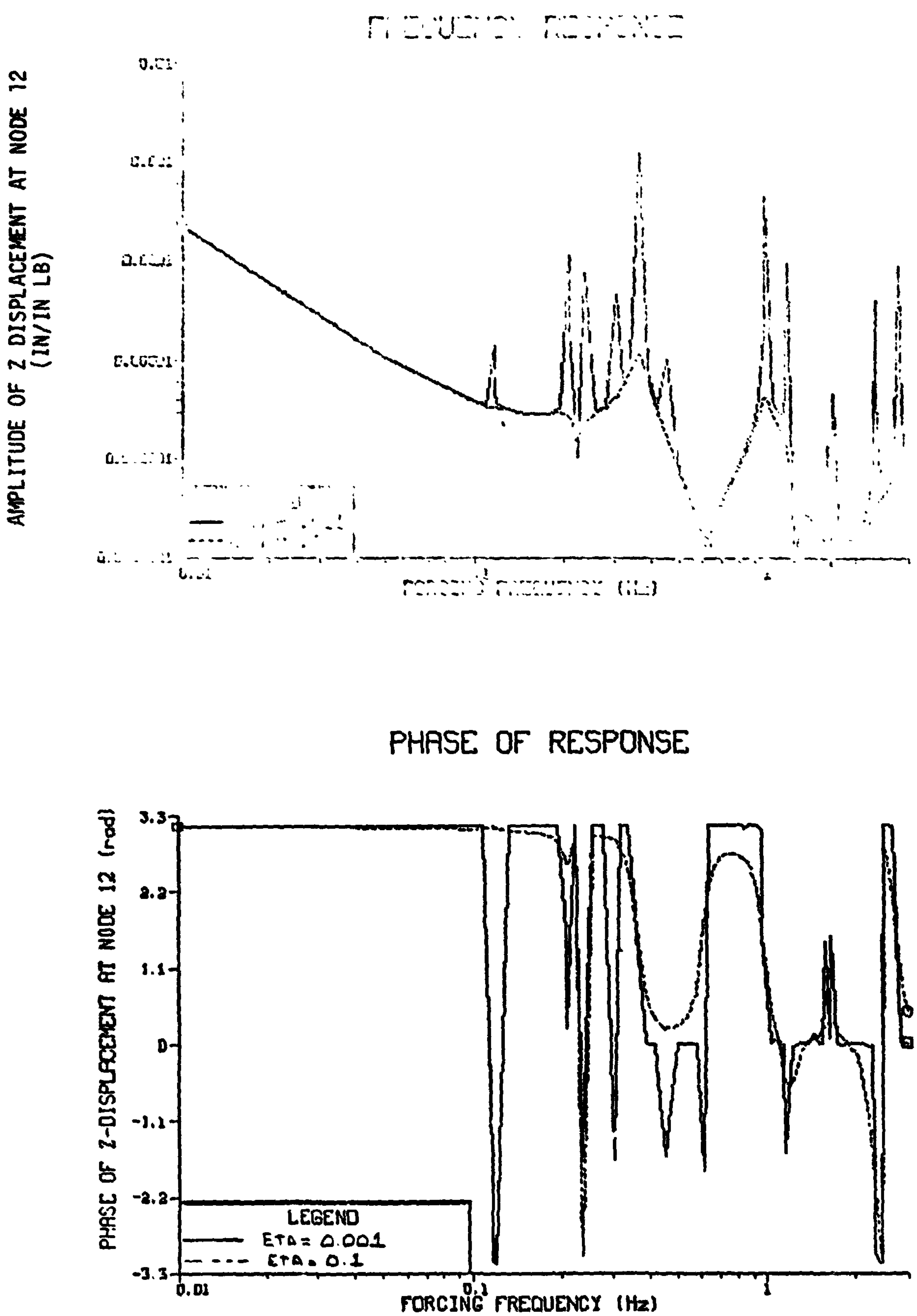


Figure 5.4.4-10 Z Response of Node 12 from a Unit θ_x Torque at Node 10

Referring to Figures 5.4.4-7 through 5.4.4-10, which show the translational responses to the unit torque at node 10, similar significant reductions are made by increasing the damping. It is worth noting that the unit responses in the Y and Z directions differ by an order of 10 in the rigid body range but become equal at 0.4 Hz. The response amplitude to a ± 34 NM input would be ± 2.3 cm in both Y and Z directions. This would be reduced to ± 0.23 mm or less with the increased damping.

Enhanced damping is, therefore, an approach to dealing with low frequency resonance problems in these large structures. Higher values of damping (η = 0.2 to 0.5) than shown do not give substantially greater amplitude reduction but do further smooth out the phase response of the structure. The incorporation of enhanced damping in a design substantially reduces the structural amplification and simplifies control system filter design because of the phase change smoothing effect.

5.4.5 Important Consideration Needing Resolution

The most important consideration that will influence the structural design is the potential requirement that the pointing systems may impose on the SASP structure. This issue needs to be resolved in a timely manner.

5.4.6 Work Accomplished

Stiffness and complexity characteristics for five fixed and two deployable truss structural modules have been determined. A structural module optimization has been completed and the optimum structural module has been selected for the SASP structure. Aluminum, titanium and graphite/epoxy were evaluated as candidate structural materials for SASP and graphite/epoxy has been selected. This evaluation considered the material radiation resistance as well as CTE stability.

The minimum required structural frequency has been established as .1 Hz from overall attitude control considerations. Preliminary investigations have indicated the pointing systems may impose a structural requirement on SASP. Structural temperature and temperature gradient extremes have been predicted for a grapnite/epoxy and insulated aluminum cross arm (inertial orientation), a graphite/epoxy trail arm (earth orientation) and the stand-off structure radiator panels (inertial orientation). A NASTRAN structural dynamics model has been established. Frequencies and mode shapes have been determined and frequency and transient response analyses have been conducted that show the potential benefit of implementing enhanced damping on SASP.

5.4.7 Conclusions and Comments

From the studies conducted herein, the following conclusions can be drawn.

1. The IB-B structural module (54" x 54" x 98") is the optimum truss configuration for SASP.

2. Aluminum, titanium and graphite/epoxy were evaluated for the structural material and graphite/epoxy was selected.

3. The minimum structural frequency requirement is .1 Hz from overall attitude and control considerations.

4. There is some reason to believe that the experiment pointing systems may impose a requirement on the structure. This issue, which is beyond the scope of this study, needs to be studied and resolved in a timely manner.

5. Structural temperature predictions for a graphite/epoxy structure indicate a T max = 163°F, T min = -127°F and longeron to longeron ΔT AVG MAX = 205°F.

6. Temperature predictions for an insulated aluminum cross arm in inertial orientation at β = 52° indicate a ΔT AVG MAX = 104°F and is essentially constant throughout the orbit. This concept should be studied further as an alternative to graphite/epoxy for the cross arm structure.

7. Structural distortion temperature gradients of the stand-off structure surrounded by radiator panels should be less than 138°F. An insulated aluminum stand-off truss along with an uninsulated aluminum stand-off truss that considers the addition of sensors to the support module as a new attitude reference point should be evaluated.

8. A NASTRAN structural dynamics model of the 2nd Order Extended SASP indicates the minimum structural frequency of .1 Hz is satisfied.

9. Frequency and transient response analyses indicate that implementing methods of enhanced structural damping can be of significant benefit to SASP.

5.5 ATTITUDE CONTROL SYSTEM DESIGN

This section describes the ACS design. Trades and analyses that were performed in the derivation of the design and in defining its performance are presented in Section 4.2 . Table 5.5-1 below summarizes the distribution of ACS function between configuration elements.

POWER SYSTEM	PLATFORM	PAYLOADS
• Orientation -2 attitude error	• Tailored Pointing (Rotatable Arms)	• Fine Pointing
• Stability	• Augmented Momentum Dump (Set of 4 Torquer Bars)	• High Accuracy Stabilization
• Momentum Dump (Set of 4 Torquer Bars)	• PLD Sensor Feedback -20 arc min Attitude Error	

Table 5.5-1 Attitude Control System

The platform attitude control and orientation will be provided by the Power System ACS. Attitude of the Platform will be held to an accuracy of 2 degrees by the Power System. Feedback from payload sensors will be used to refine attitude reference of the Platform and its elements to around 20 arc min. Stability is expected to be approximately 10 arc min.

In order to increase the momentum desaturation capability of the Power System magnetic torquer bars are added to the Platform. Currently the number of bars added to SASP is four (sets of 4 bars are reasonable from control standpoint). This is subject to review with the sensitivity of principal axis misalignment correction being only 1/4 to 1/2 degree per set of torquer bars.

Control of experiment pointing is provided by the $\pm$180 degree rotating arms on the Second Order Platform and by the 4-position hinge/mini-arm in the First Order Platform. Fine pointing must be provided by the payloads.

5.6 COMMUNICATIONS AND DATA MANAGEMENT

5.6.1 Overall Requirements Summary

The SASP communications and data management design is driven by two types of requirements. One type includes those requirements imposed by the TDRSS interface. These requirements define the communication frequencies, encoding, and modulation, data rate limits, power, sensitivity, and scheduling constraints. The second type of requirement includes those defined by the payload data interface, such as command rate, scientific and engineering data rates, timing reference accuracy, and data processing support. Figure 5.6.1-1 shows a set of "typical" payload data requirements. Figure 5.6.1-2 shows the distribution of payload scientific data rates for a set of 62 payloads examined during the study. Five of the 62 payloads have peak data rates in excess of 10 Mbps and two (Earth SAR and Ocean SAR) have peak rates of 120 Mbps.

Certain payloads require "real-time" data at a low rate (typically 50 Kbps) for use in interactive payload control. Command rates specified for payloads are typically 2 Kbps or less at a low duty cycle. A number of payloads require video or other analog data to be transmitted to the ground. Data processing support required by payloads varies in degree, but, as discussed

earlier, the trend is toward more and more autonomy in on-board processing capability.

Digital Data Rate: <10 MBPS Peak (93% Payloads)
120 MBPS Worst Case Peak Rates

Video/Analog Data: < 500 kHz Analog
1 or 2 Channels Slow-Scan TV
Fast-Scan TV — Some Payloads

Acceptable Data Delay: Some Data (<50 KBPS) Real Time for Interactive Control — Delays of 1 Orbit to Several Hours OK for Bulk of Data

Uplink Commands and Data: Low Rate (1 or 2 KBPS Peak)

Timing Reference Requirement: 10^{-5} sec Accuracy

Figure 5.6.1-1 "Typical" Payload Data Characteristics

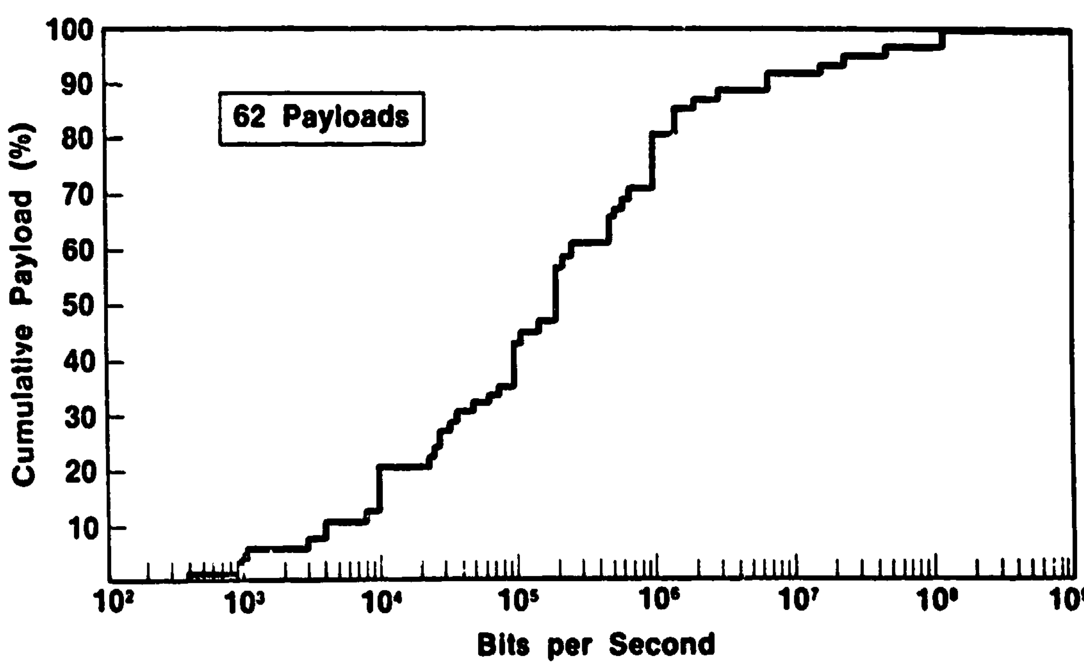


Figure 5.6.1-2 Percent of Payloads Having Data Rate ≤ X Bits per Second

5.6.2 Important Factors and Considerations

In addition to the requirements imposed by the payload and TDRSS interfaces, other factors and considerations influenced the communications and data management concept design; these included: growth capability, technology availability, Spacelab payload accommodation, and integration considerations. Growth capability needs to be incorporated to handle potential increases in payload command and data rates throughout the useful life of the Platform and to handle growth in on-board processing requirements.

The ability to accommodate Spacelab payloads with mini[illegible] change may be an important consideration. On the other hand, payload design modifications to accommodate the longer time in orbit offered by SASP and to allow automated or ground control rather than on-board crew control may be such that data interface modifications may not be significant. More study is required to determine the appropriate response to this consideration.

A key factor in the concept design has been the desire to simplify the on-orbit payload to SASP integration process. This activity is shown in Figure 5.6.2-1 in the content of the overall experiment integration flow. Of particular concern is the software integration where software on the SASP side of the interface must be integrated with software or hardware on the payload side. Past experience has shown that this can be a time-consuming operation. Some key elements to a successful on-orbit integration of the payloads with SASP are shown in Figure 5.6.2-2. Of these elements, payload autonomy, interface standardization, and software modularity are of particular importance to the data management system design.

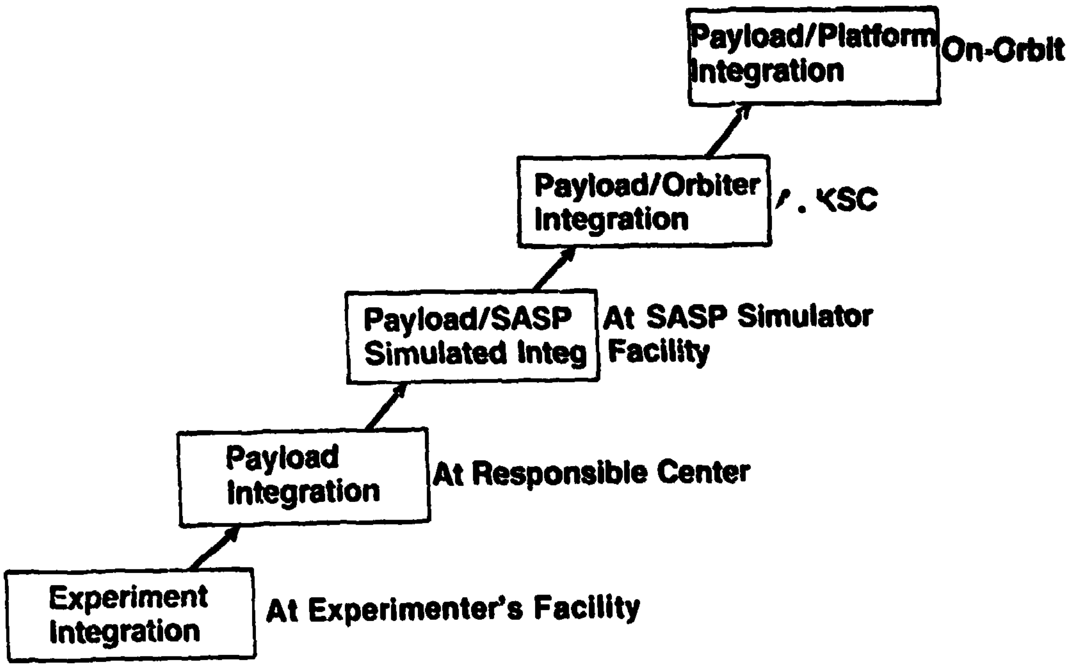


Figure 5.6.2-1 SASP Experiment Integration Process

- **Payload Autonomy**
  - **Experiment**
  - **Pallet**
- **Standard Interfaces**
  - **Experiment**
  - **Pallet**
- **Software Modularity (Central Processor)**
  - **Housekeeping Data & Commands**
- **Prelaunch Integration with SASP Simulator**
  - **Hardware Simulator**
  - **Software Simulator**

Figure 5.6.2-2 Approach to On-Orbit Payload/Platform Integration

5.6.3 Work Accomplished

Communication and data management concept designs were defined for the First Order and Second Order Platform. The First Order Platform concept is shown in Figure 5.6.3-1. This concept essentially uses the Reference 25 kW Power System communication and data management concept with the recommended addition of payload data storage capability. The rationale for adding the data storage is discussed in Section 4.3 (Task 4). In addition, RIU's are required on each of the First Order Platform arms to provide control and monitoring capability for the arms and the associated mechanisms. To accommodate the eventual installation of the Second Order Platform on the end port of the Power System, the scientific data rate capability of that port should be increased to at least 220 Mbps. Increase of the Ku band return link data rate and the end port data rate to 300 Mbps should be considered to provide growth capability up to the TDRSS rate limit if the cost of doing so is not prohibitive.

The Second Order Platform data management system concept is shown in block diagram form in Figure 5.6.3-2. As discussed in Section 4.3 (Task 4). multiplexing and recording capabilities are included to supplement the capability provided in the First Order Platform. These increased capabilities are needed to accommodate the larger number and increased complexity of the payloads expected on the Second Order Platform.

The data bus from the Power System data processors is carried through the platform and made available to the payload ports. Commands and engineering data would be transferred on the data bus. Control and monitoring of platform subsystems is implemented through RIU's attached to this bus.

Dedicated microprocessors will be use SAS to provide local control of SASP subsystems where there i ffload the PS computers.

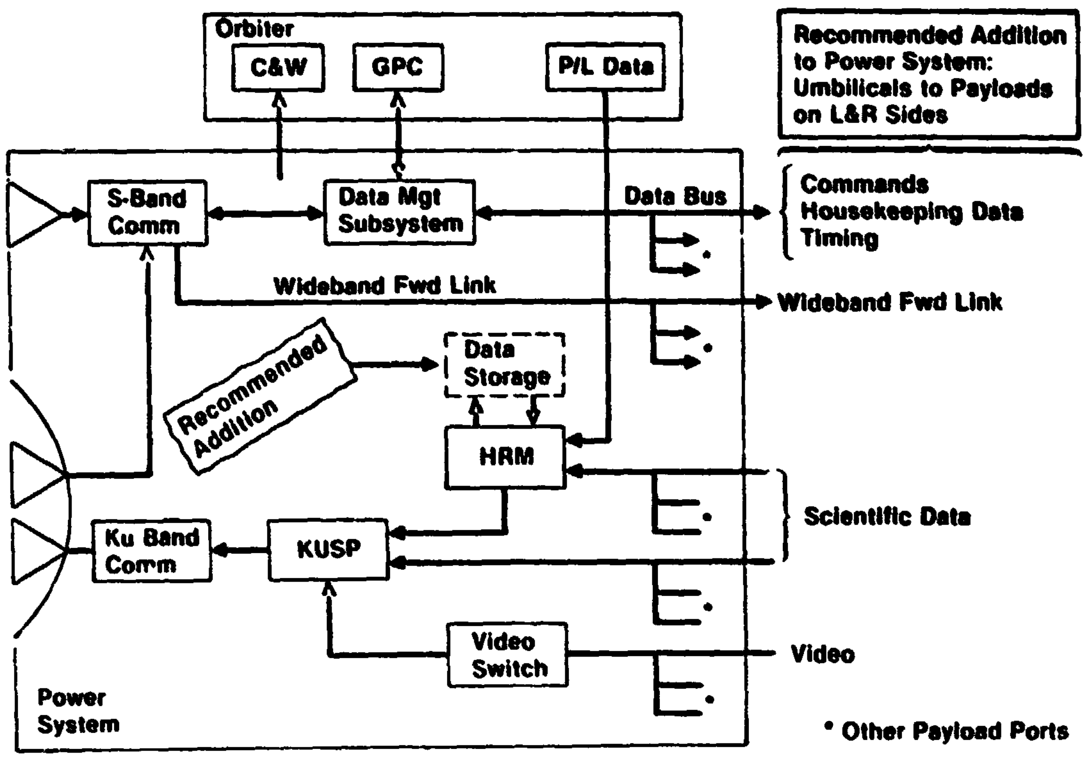


Figure 5.6.3-1 Comm and Data Handling - First Order Platform/ Power System

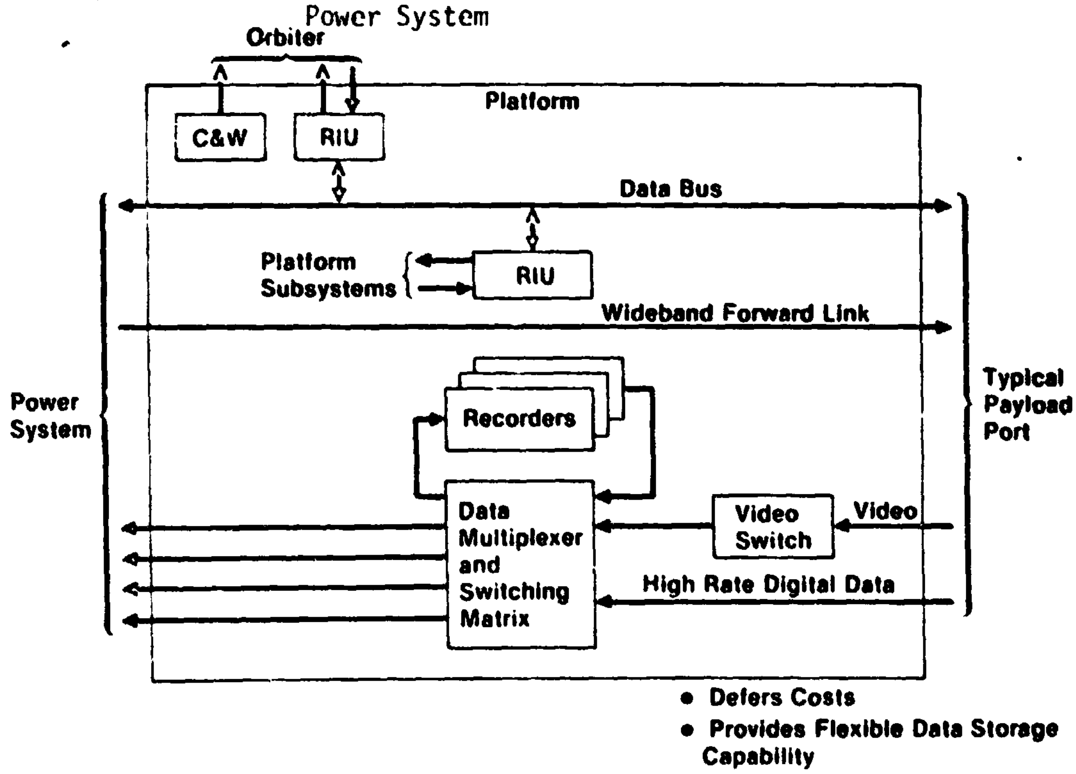


Figure 5.6.3-2 Data Management Subsystem - Second Order Platform

An interface with the Orbiter allows the transfer of control and monitor data and provides a path for caution and warning signals to the Orbiter crew.

The data multiplexer and switching matrix allow high rate payload scientific data to be multiplexed, recorded, and transferred to the Power System in a flexible manner to accommodate various combinations of data acquisition rates and end-to-end system loading.

Figure 5.6.3-3 shows how the communication and data management system would accommodate a proposed payload grouping. This figure shows the basic scientific data requirements of each payload in the group. The two payloads with extremely high peak rates, ERSAR and SOT, can be accommodated; however, it should be noted that that data management system performance, as well as the TDRSS and ground network performance, are quite sensitive to the operating timelines and duty cycles of these payloads.

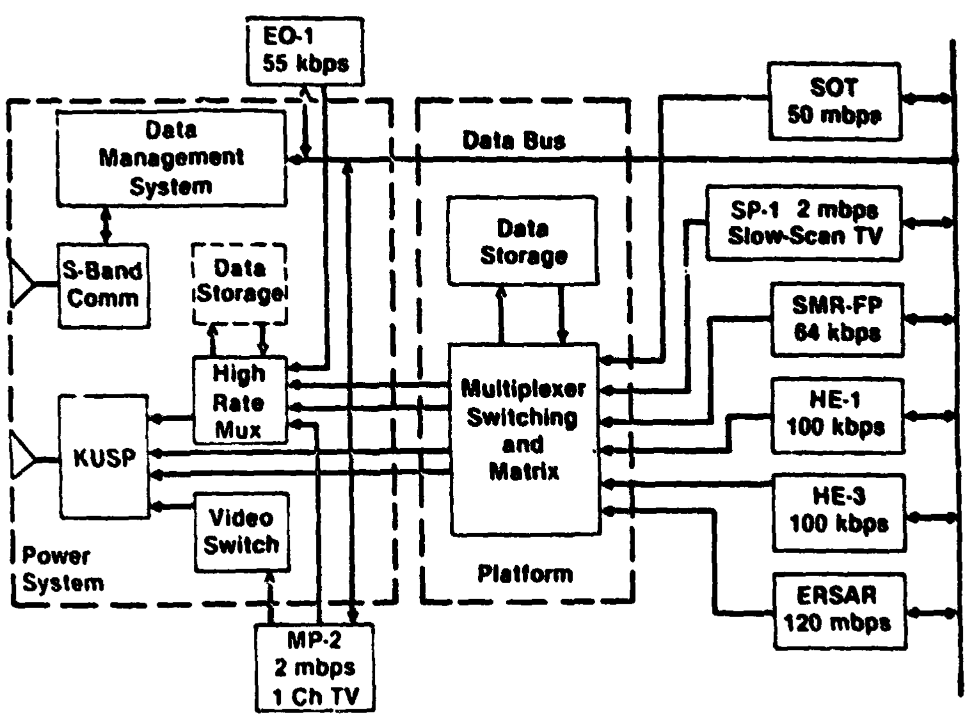


Figure 5.6.3-3 Data Subsystem Accommodation of B-10 Payload

5.6.4 Conclusions and Recommendations

The concept defined for the SASP communication and data management is capable of accommodating a wide range of payload data support requirements Operating flexibility has been stressed so that the system can accommodate varying types and groups of payloads. Payload data storage is provided to allow operation in a store and dump mode to provide flexibility in TDRSS utilization.

Payload autonomy in the data processing area has been stressed to ensure maximum ease of payload to platform integration.

Additional work should be done in the definition of processing requirements and concepts for payload pointing systems and in the area of defining concepts for accommodating Spacelab payloads with minimum overall impacts.

5.6.5 Further Discussion - Spacelab Payload Accommodation

Payload data interfaces with the Spacelab typically include interfaces with a Spacelab Remote Acquisition Unit (RAU) for commands, engineering data, and timing, and with the Spacelab High Rate Multiplexer (HRM) for scientific data. A separate video data interface is included when required. Signal conditioning, buffering, and synchronization must be provided on the payload side of the interface. This payload data interfacing equipment can be modified to provide compatibility with the SASP data system. The scientific data interface is expected to require little or no change since the Reference Power System uses a Spacelab HRM. The command and engineering data bus, however, is different (a STACC bus used in the Reference Power System).

Figure 5.6.5-1 shows a typical Spacelab/Payload data interface with Spacelab Payload Standard Modular Electronics (SPSME) used on the payload to interface

with the Spacelab. SPSME is a set of standard functional modules developed by MDAC for NASA to perform the interface function for Spacelab payloads. SPSME can be readily reconfigured to adapt Spacelab payloads to the SASP data management system by providing one or more new modules. Figure 5.6.5-2 shows a possible configuration of SPSME supporting a payload to SASP data interface. Note that only one new module is required for this configuration.

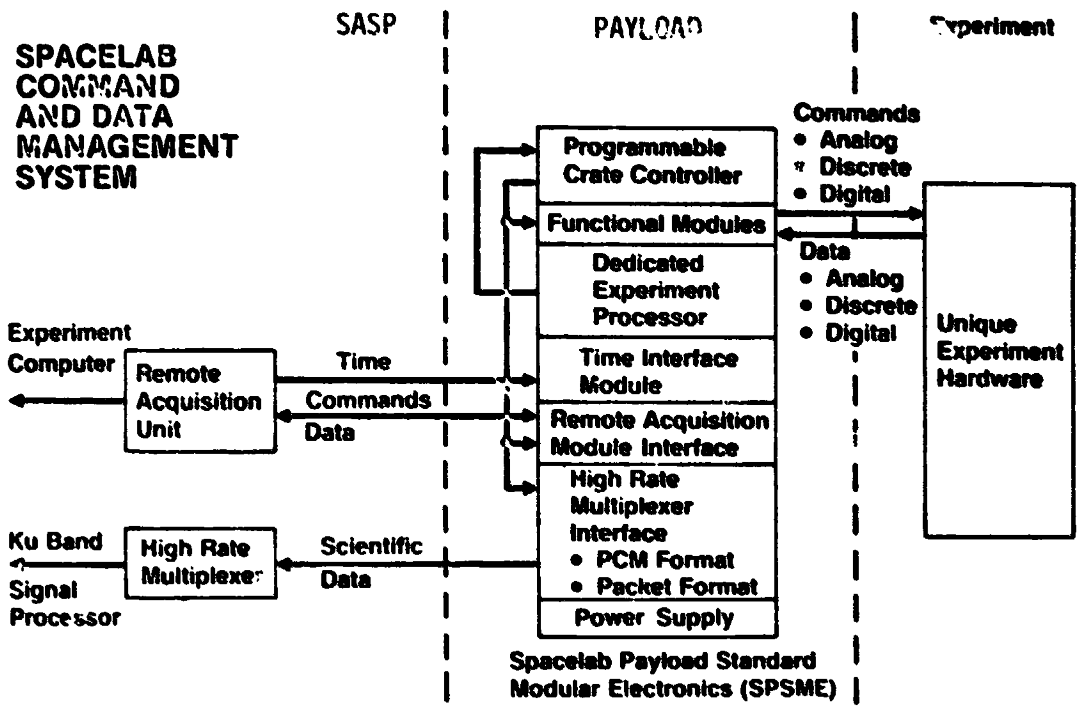


Figure 5.6.5-1 Typical Spacelab Experiment End-to-End Command and Data Flow

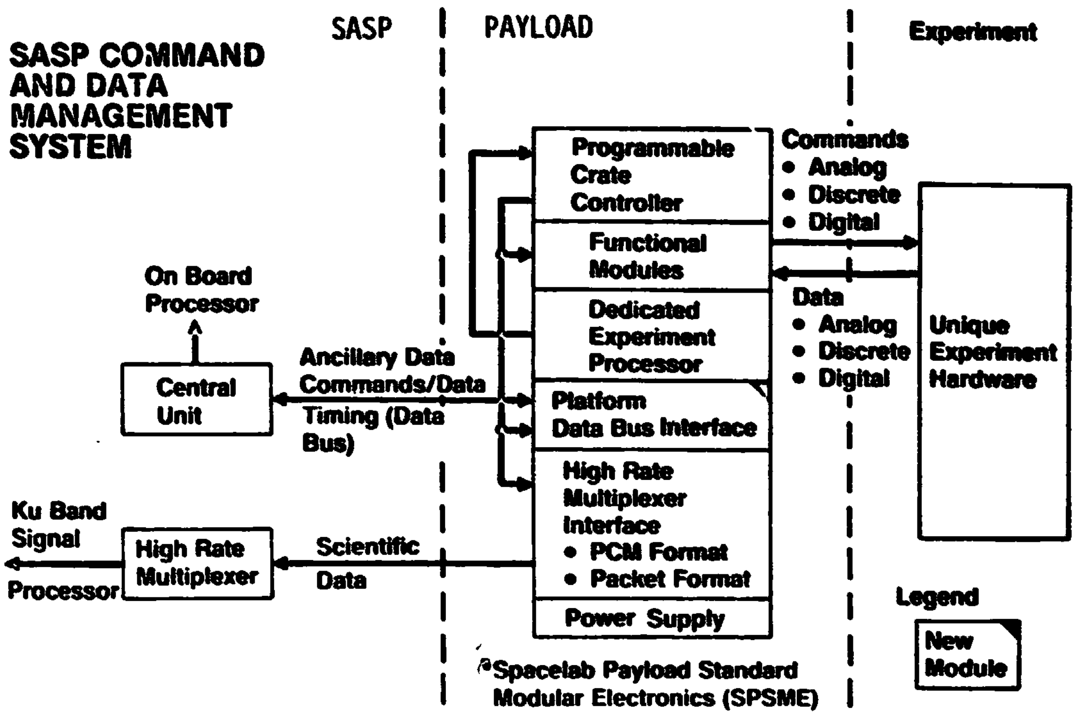


Figure 5.6.5-2 Typical SASP Experiment End-to-End Command and Data Flow

SPSME also has provisions to include a dedicated experiment processor to support experiment control, data acquisition, and data processing. As discussed in Section 4.3 (Task 4), data processing capability at the payload is strongly preferred over payload data processing in a centralized (platform) processor.

While not all Spacelab payloads will use SPSME, most will have some functional equivalent that can be modified to accommodate a SASP interface. The extent and cost of that modification will depend, among other things, on the modularity of the interfacing equipment.

5.7 POWER DISTRIBUTION

5.7.1 Overall Requirements Summary

The principal requirements placed on the power distribution system can be summarized as follows:

- Distribute the required type and amount of power to payloads and supporting subsystems.
- Provide continuity of the equipment grounding system across non-metallic sections of platform structure.
- Utilize Power System (PS) single point structure ground system.
- Use hardwire returns for all power circuits.
- Supply power to supporting subsystems at 30 VDC nominal.
- Readily accommodate growth from First Order to Second Order to Extended Second Order Platform configurations.
- Develop viable designs for cable stowage/deployment for hinged/ expandable truss sections.
- Provide flexibility for selecting alternate source buses for payloads and support subsystems.
- Accommodate peak power demands in the most economical manner.
- Define any unique interface requirements placed on the PS by the Platform.

Power requirements for the mini-arm berthing ports on the First Order Platform are set at the capability of the PS by the Materials Experiment Carrier (MEC). Expansion to the Second Order Platform configuration provides additional ports to supply lower viewing payloads on cross arms extending from the Platform Support Module. A mini-arm identical to those on the First Order Platform is attached to the aft position of the Support Module. The Extended Second Order Platform adds more of the lower power ports by addition of cross arm extensions or a trail arm.

5.7.2 Important Factors and Considerations

The platform mini-arms distribute a nominal average power of 25 kW at either 30 V or 120 V. Peak ratings of the PS 30 V section and 120 V section are 35.5 kW and 27 kW respectively with a potential for the 120 V section to deliver 36 kW. The distribution system of the mini-arms is sized to handle 150% of rated average power and, therefore, can distribute the 62.5 kW rated peak power of the PS.

No requirements have been identified for a payload dedicated essential bus. The TRW MEC report dated 11 June 1980 makes provision for a selectable low power (~1 kW) priority bus from the three-bus 30V interface or the two-bus 120 V interface, which are provided by the platform mini-arms. Switchable redundant source buses in the Platform Support Module are provided for all ~~low~~ Changed to 20 kW/30 kW at Final Briefing power (~~6.0 kW average/9.3 kW Peak~~) payload interfaces on cross arms and extension arms. Some scar weight penalty is incurred in the Basic Second Order Platform to provide this and other flexibility features for the extended platform family. Means for supplying cross arm payload peak power greater than 9.3 kW are reported under Task 4, Subsystem Trades, with conclusions summarized later in this section.

The nominal 30 volt distribution system is sized to maintain payload interface voltages about 26.0 volts at rated peak power with the PS regulators set for 32.0 volts maximum/31.4 volts minimum (±1% band) at the PS/Platform interface. The Platform/Orbiter interface is more restrictive. In this case the criteria is to maintain Orbiter/Spacelab interface voltage at 26.6 volts minimum for a peak load of approximately 11 kW. Data generated by MDAC for the NASA Power Extension Package (PEP) study program indicates this criteria can be met by using eight (8) "0" gauge wires for one of the three 30 V circuits

from the PS via the Platform to Orbiter Main Distribution Assembly No. 3. Emphasis is placed on design for maximum isolation of payloads to minimize possible interference to one payload from transients produced by another. A minimal weight penalty is incurred for this capability.

5.7.3 Work Accomplished

Highlights of work accomplished are listed as follows:

- Developed payload and support subsystem power requirements.
- Developed Second Order Platform distribution system design for maximum payload isolation, flexibility for bus load assignments, and simplicity of expansion to Extended Second Order Platform consistent with minimum trade penalties.
- Evaluated approaches to circuit protection and switching.
- Analyzed methods for handling high peak power demands and selected a preferred approach.
- Made recommendations for changes to reference concept 25 kW Power System in PM-001 to accommodate platform unique interfaces.
- Selected a cable design for crossing hinged and rotating (up to ±180°) joints using superflex wire.
- Identified need for development of high voltage components (i.e., 120 VDC and higher) to promote viable alternatives to distribution and utilization at less efficient lower voltages.
- Generated design approach to platform distribution design for high power, pressurized, manned modules.
- Investigated applications for bypassing 120 volt regulators to supply dedicated high power payloads directly at battery voltage.

5.7.4 Conclusions and Comments

The First Order Platform has the capacity to distribute Power System rated peak power to all payload ports. The Materials Experiment Carrier (MEC) is a prime user of this capability.

The Second Order Platform provides ports dedicated to ~~lower~~ power (~~6.0 kW~~ 20 kW average/~~9.3 kW~~ 30 kW peak) payloads. Viewing experiments are prime users of this capability. The Extended Second Order Platform family provides additional ports for the lower power users.

All platform configurations can employ three mini-arms, each of which will handle the maximum available output of the 25 kW Power System. Payload power is available at all ports at either 30 V or 120 V or a combination of the two up to their combined ratings, depending on other mission user requirements.

Maximum isolation of payloads is provided by use of radial feeds from switchable, (selectable) source buses. Conductors for nominal 30 V distribution are sized to maintain payload interface voltage at 26.0 V or higher for rated peak power conditions. The minimum interface voltage for the 120 V system is 108 V. Peak load demands exceeding distribution system maximum ratings are supplied by peaking batteries provided by the user. No provision is made for distributing AC power to payloads. Insufficient data is available to size central inverters (other than those dedicated for platform thermal control system pumps). Therefore, any AC power required is to be provided by the user.

Recommendations for modifications to interface provisions in the 25 kW Power System reference concept are reported under Task 3. Timely development of required components for high voltage, high power distribution and utilization is strongly recommended in support of PS/SASP and related applications.

5.7.5 Discussion

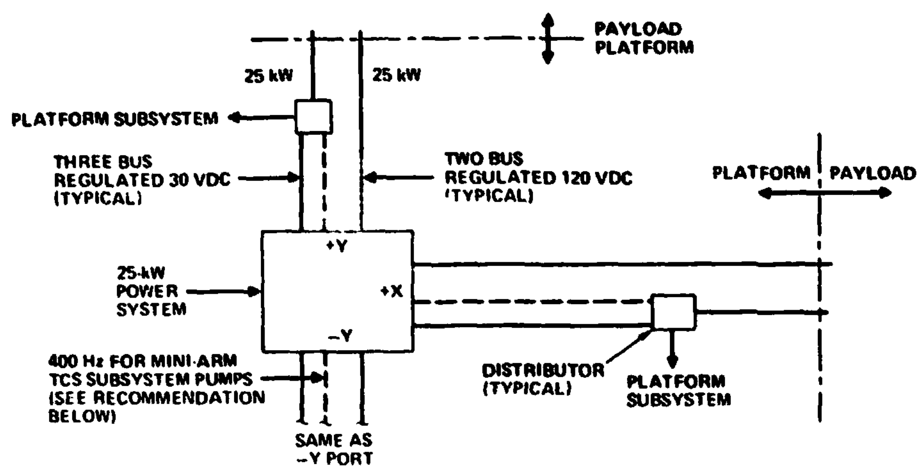
The platform power distribution system has evolved conceptually into options ranging from distributing both DC and AC power, with provisions for utilizing the maximum peak DC power available from the 25 kW Power System (PS), to a more elemental system for distributing and controlling primary DC power only, with peak load demands exceeding nominal distribution capacity being supplied by local peaking batteries. The scope of payload power interfaces ranges from those provided for a First Order Platform, where power is distributed directly from PS berthing ports, to an extended Second Order Platform which adds distribution from a central support module to payloads on cross arms and trailing arms. The baseline concept provides for growth from first order to second order with a "kit" approach to being used to achieve maximum second order capability.

A block diagram of the first order power distribution system is shown in Figure 5.7.5-1. Note the recommendation to provide coolant pumping in the PS, thereby eliminating the 400 Hz interfaces.

The 25 kW 120 V interfaces at the +Y and -Y ports are additions to the PS reference concept defined in PM-001. Also the +Y and -Y 30 V interfaces are increased from 6 kW to 25 kW to accommodate MEC. While not shown, use may also be made of the +Z port which can supply rated 25 kW capacity at either 120 V or 30 V.

Growth to the Second Order Platform configuration provides power usage for payloads docked at cross arm berthing ports at the levels given in Table 5.7.5-1. Rated capacities at the interfaces are ~~6.0 kW~~ 20 kW continuous/~~9.3 kW~~ 30 kW peak, ~~of which 4.6 kW continuous/6.9 kW peak is allocated to payload elements (experiments) per se.~~ The table also gives a breakdown of both payload and

platform subsystem power usage. Requirements for payload pointing (Dornier system) and payload subsystem equipment power were coordinated with TRW. Note that no power is allocated to payload subsystems for thermal control. A central thermal control system (TCS) is provided by the Platform. allocation of 640 watts at 400 Hz is shown for TCS pumps located in the Platform Support Module (SM).



- 25 kW REGULATED 30 VDC AND 120 VDC CAPABILITY PROVIDED AT +Y AND -Y PORTS AND +X PORT TO ACCOMMODATE MEC IN ADDITION TO LOWER POWER VIEWING PAYLOADS
- RECOMMEND DELETE TCS PUMPS AND 400-Hz DISTRIBUTION FROM MINI-ARM SUBSYSTEM AND PROVIDE PUMPING IN PS (SEE TCS DESCRIPTION)

Figure 5.7.5-1 First-Order Platform Power Distribution Block Diagram

NOTE: Power at each port changed to 20 kW/30 kW peak at Final Briefing

Power Allocation in Watts

Payload	Continuous	Peak
• Payload Element	4,000	6,000
• Pointing (Dornier)	617	1,645
• Subsystem		
Computer and I/O	525	525
Support Electronics	182	182
	5,324	8,352
• Growth Allocation	676	976
Totals	6,000	9,328
Platform		
• High Rate Multiplexers	400	400
• High Rate Digital Recorders	250	500
• RIU's	35	35
• Thermal Control	640	640
• Trail Arm Rot. Drive	50	200
• Other Drives/Mechanisms/ Viewing Lights/TV Cameras	Intermittent	
	1,375	1,775
• Contingency	225	275
Totals	1,600	2,050

Distribution Interfaces

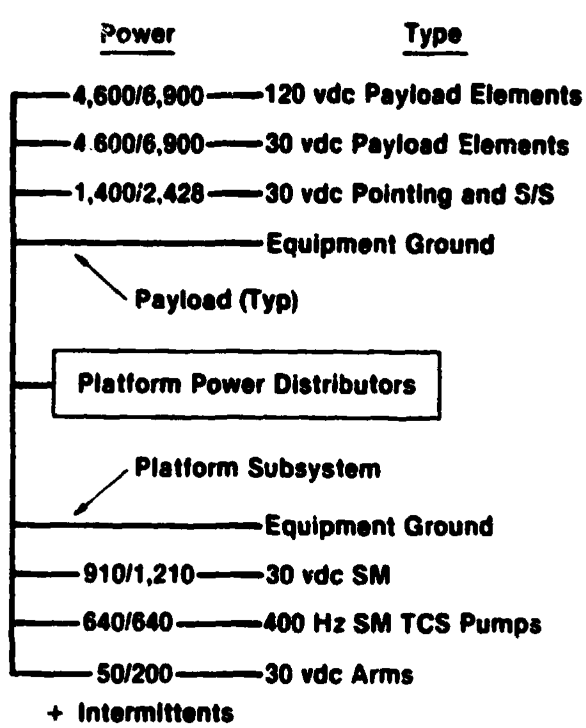


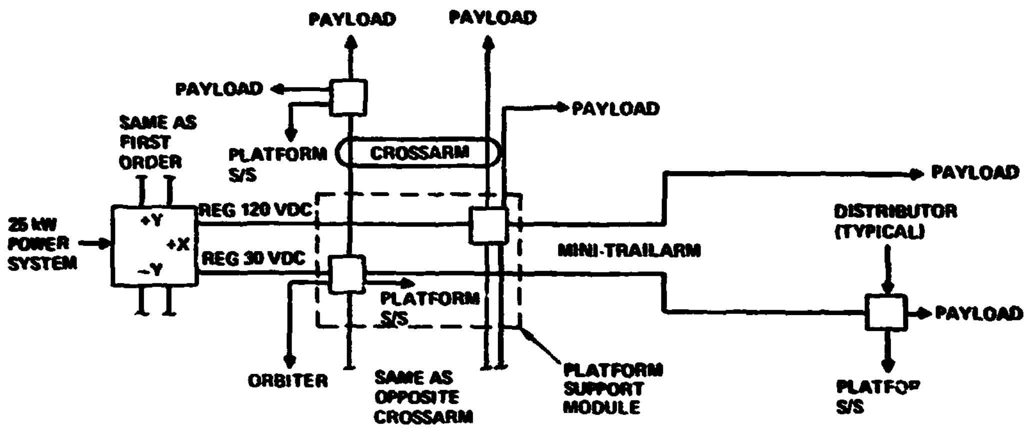
Table 5.7.5-1 Power Allocations/Distribution Interfaces, SAS Second-Order Platform Configuration

The allocation of 4000 watts continuous power for payload elements is unchanged from the Midterm Briefing. However, peak power has been reduced from 8000 watts to 6000 watts. This reflects the specific constraint in DOD RFP F04701-79-R-0060, Experiment Requirements for Space Test Program Sortie Support System, Appendix 4 to Annex A to Attachment 1, which limits experiment peak power to 1.5 X experiment average power. Use of the 1.5 factor also is in keeping with criteria used in previous platform studies conducted by MSFC. Experiment data analyzed by MDAC has shown limited instances of higher ratios of peak to average power, but it is felt that the 1.5 X factor should be used for experiments in the 6 kW class unless a higher factor is developed from the TRW experiment data base study.

Power requirements for the platform subsystem are broken down to the component level versus the subsystem level reported at Midterm. Allocations of power to the platform subsystem, payload elements, and payload subsystems, including provisions for growth and contingencies, are indicated by power level (continuous/peak) and type (120 VDC, 30 VDC, 400 Hz) in the interface diagram on the right. Equipment grounds continue to be shown to provide continuity of the grounding system for equipment on mini-arms, cross arms trail arms, and standoff, all of which are baselined to use graphite epoxy structure. The Platform Support Module is aluminum which provides an effective ground plane.

The full capability interfaces at the PS +Y and -Y ports are retained in the Second Order Platform, and the mini-arm formerly at the +X port is attached to the platform support module aft berthing port as indicated by the block diagram in Figure 5.7.5-2. Distribution of AC power to payloads is not provided because of the lack of a hard requirements base for cost-effective system sizing. User provided batteries are required to supply peaking power if experiment (payload element) demand at the lower power cross arm ports exceeds ~~6.9~~ 30 kW.

The Second Order Platform incorporates the Support Module with its central command/data and thermal control systems. In addition to its expanded capability to accept different and varied payloads, the Platform provides a berthing mechanism for the Orbiter. Three 30 VDC buses are provided at the Orbiter/Platform interface to support the Orbiter and its payloads in a sortie mode. Two of the three buses are rated to supply a nominal 7 kW each for Orbiter loads. The third bus is rated to supply approximately 11 kW at the Orbiter/Spacelab interface. The basic second order configuration can be expanded to serve additional payloads by installing "kits" which extend either the



- ALL PAYLOAD INTERFACES CAPABLE OF SUPPLYING 6 kW CONTINUOUS POWER. IN ADDITION, PS +Y AND -Y 30 VDC AND 120 VDC INTERFACE,
- TRAIL ARM PORT 120 VDC AND 30 VDC INTERFACE, AND ORBITER INTERFACE ARE CAPABLE OF SUPPLING 25 kW (LESS PLATFORM SUBSYSTEM LOADS AND DISTRIBUTION SYSTEM LOSSES)

Figure 5.7.5-2 Second-Order Platform Power Distribution Block Diagram

cross arms or trail arm or both. The two ports on each of the kits are rated ~~6~~ 20 kW continuous/~~9.3~~ 30 kW peak at both 30 VDC and 120 VDC, same as the cross arm ports on the Basic Second Order Platform. The kit which extends the trail arm is inserted between the basic trail arm structure and the Support Module. This kit incorporates a 360° rotary joint with a slip ring/roll ring system capable of transmitting maximum available power (nominal 25 kW less platform subsystem loads and distribution losses) across the interface. This is the only configuration that requires a slip ring/roll ring system. Power transfer across all other rotary joints (±90°, ±180°) is accomplished by using flexible trailing cables.

The trail arm "kit" also is unique in that coolant fluid is not transferred across the 360° rotary joint. Inverters are provided in the trail arm support equipment kit to supply 400 Hz power to the self-contained thermal control system pumps.

Superflex wire is used in flexible trailing cables for crossing hinged as well as rotating joints and for deployable cable in expandable truss sections. This approach also was taken by MDAC for power transfer across joints on the Orbiter remote manipulator system in the MEP application.

The 30 V power distributors provide buses, power monitoring, circuit protection, and switching for payload and platform systems as required. A block diagram of mini-arm power distribution is shown in Figure 5.7.5-3. A more detailed diagram indicating power distribution for the second order cross arm is given in Figure 5.7.5-4. This scheme uses radial circuits to all payload elements and is the preferred approach developed in Task 4, Subsystem Trades.

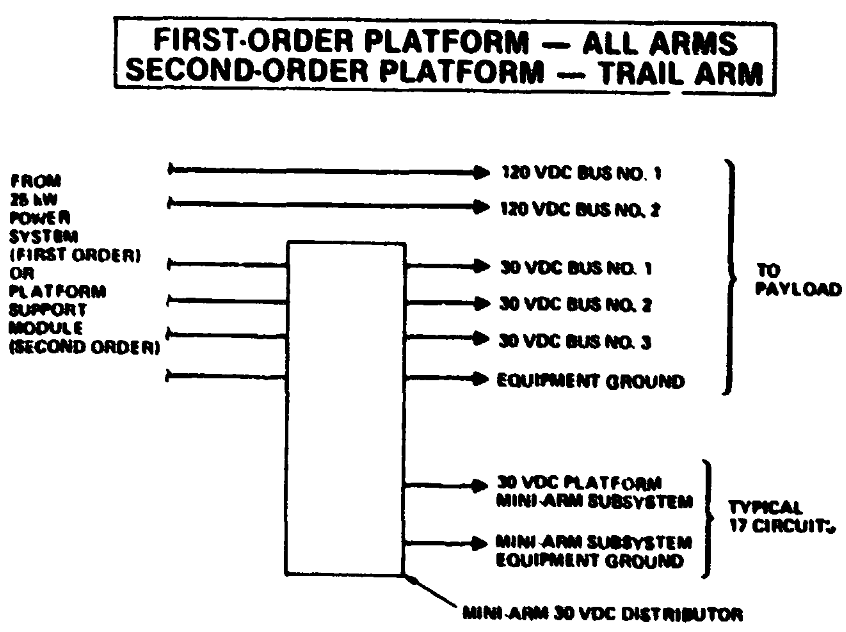
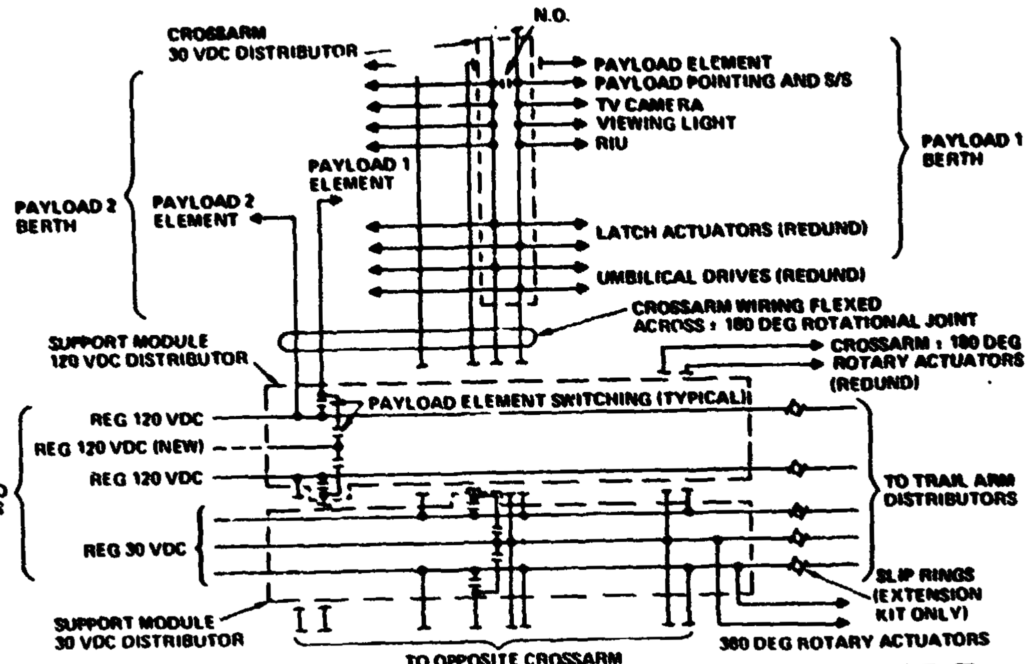


Figure 5.7.5-3 Mini-Arm Power Distribution



- PROTECTIVE DEVICES OMITTED FOR CLARITY
- SWITCHING SHOWN ONLY WHERE REQUIRED TO INDICATE BUSING CONCEPT
- POWER CIRCUITS TO PLATFORM SUPPORT MODULE DATA/COMMAND/THERMAL SUBSYSTEMS NOT SHOWN
- ORBITER INTERFACE NOT SHOWN

Figure 5.7.5-4 Radial (Isolated) Circuits to Crossarm Payload Elements

The advantages of this approach relative to others considered are that it (1) provides maximum isolation between payload elements for both the basic and extended Second Order Platforms, (2) increases isolation between payload subsystems, (3) offers higher indicated reliability, and (4) offers lower indicated system cost, although at the expense of scar weight to readily accommodate growth to the extended second order configuration. The principal disadvantages are (1) increased cable weight, and (2) increased number of trailing cable installations to cross rotating interfaces. The total number of cables may be reduced, however, due to elimination of distributors for the payload element circuits.

Also included but not shown in Figure 5.7.5-4 are redundant 400 Hz inverters for the TCS pumps, together with required switching and circuit protection in a dedicated AC power distributor. Support Module subsystem dc loads are served from a redundantly supplied 30 V auxiliary bus in the Support Module 30 V distributor.

Power is supplied from the PS to the SM distributors over three 30 VDC regulated circuits and three regulated 120 VDC circuits. The reference concept 25 kW Power System provides for two regulated 120 VDC interfaces; the third circuit was proposed in the SASP Midterm Briefing to increase platform distribution flexibility and transient isolation. Provision for switching all radial payload element circuits to alternate source buses is included although not detailed in the figure. This gives flexibility to supply multiple high demand payload elements concurrently from separate buses in both the basic second order and the extended second order configuration. Capability for supplying all subsystem loads from a single source bus is provided by the contactor shown in the crossarm distributor, however, the contactor is normally open to isolate the subsystems from one another.

Various means for protecting and switching individual circuits were assessed in Task 4. The preferred methods are (1) use remote control circuit breakers or (2) power relays/contactors in series with fuses. In either case "pulse stretching" of baseline Remote Interface Unit (RIU) discrete commands will be required to operate switching devices directly or to operate switch drivers where the primary device current/operate time exceeds RIU output capability (200 milliamperes maximum for 5 milliseconds).

Both the 30 V and 120 V outputs from the Power System are regulated to within $\pm 1\%$ of the preset voltage. However, due to voltage drops in the distribution

system, the regulation band at individual payload interfaces will be greater. Nominal steady-state limits are on the order of ±5% or better (a spread of 10% or less) with absolute worst case limits up to ±10% (20% spread). Where relatively tight regulation is required, suitable conditioning equipment must be provided by the user.

An example of SASP compatibility with user requirements from a power usage point of view is indicated in Figure 5.7.5-5. The distribution of payloads shown here is taken from the Accommodation Analysis of the B-10 segment of TRW's Flight Scenario II for a 57°, 400 km orbit (3rd quarter 1987). As noted in the figure, there are no accommodation problems. All payload power requirements are within the continuous power capability (6 kW) of the payload ports.

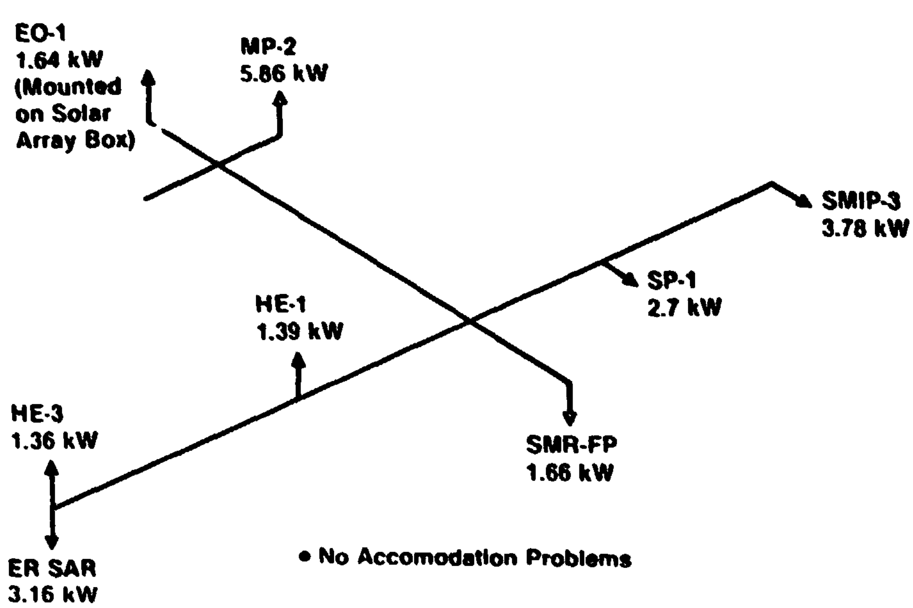


Figure 5.7.5-5 Power Requirements B-10 Case

5.8 THERMAL CONTROL CONCEPT DESIGN

As a result of subsystem trades described in Paragraph 4.5 a centralized concept was selected with platform radiators located on the standoff structure to supplement Power System radiators. Dual fluid loops are provided to transport heat from the payload via direct fluid connections to the radiators for heat rejection.

5.8.1 Overall Requirements Summary

Functional requirements for platform thermal control are to maintain payload and subsystem temperatures within limits by collecting and transporting heat to radiators when it is rejected to space. These functions must be performed for key orientations which are Z-LV with Y-POP or X-POP and X-POP with Y-PSL. Altitude variations range from 400 to 450 km.

Platform radiator geometry restrictions are imposed by the Platform standoff structure which is 1.37 meters wide and 10.4 meters long.

5.8.2 Important Factors and Considerations

Low cost is an important consideration for platforms subsystems in order to ensure a viable program. Design simplicity consistent with meeting design requirements is one method of obtaining this goal. Another approach is to make maximum use of existing hardware and technology which reduces research and development needs.

In order to obtain experimenter support, the experimenter must have a high confidence level that the Platform will provide the resources needed over the planned mission time. Therefore, a highly reliable and safe design must be provided. This may be accomplished by incorporating simple proven hardware designs. Design for on-orbit maintenance ensures a continually available platform despite unforeseen failures.

The Platform system interfaces with the Power System and the payloads and as such the designs must be compatible. Factors which are particularly important include fluid type, flow, temperature and pressure drop characteristics.

5.8.3 Work Accomplished

Effort on this task optimized and detailed the centralized concept which was chosen in the subsystem trades reported in Section 4. This concept contained four panels, one located on each of the four sides of the platform fixed standoff structure. Flow arrangement for each fluid loop is to pass through two of the panels in series, each panel has four passes. This arrangement yields a thermally efficient design with acceptable fluid pressure drop.

The radiator panels were optimized to ensure a weight and cost efficient design. A truly weight optimum design was not appropriate because the area requirements would exceed available area. Additionally, manufacturing limits on tube diameter and tube wall and fin thickness was considered. Pressure drop capabilities of existing fluid pumps were taken into account.

Six geometric factors as well as probability of meteoroid puncture, number of fluid passes for each panel and flow arrangement between panels were the design parameters. Each of these were systematically varied and a preferred value was selected in terms of a value representing an efficient design. This value in some cases was a minimum weight point, a manufacturing limit or a point where the increase in weight for a decrease in area becomes excessive.

An example is shown on the right of Figure 5.8.3-1 which varied tube spacing. A minimum weight occurs around 4.5 inches, but area requirements are excessive

at this point. As tube spacing is reduced in length, area decreases but complexity and cost increase because of the number of tubes and welds. A value of four inches was chosen as an efficient design.

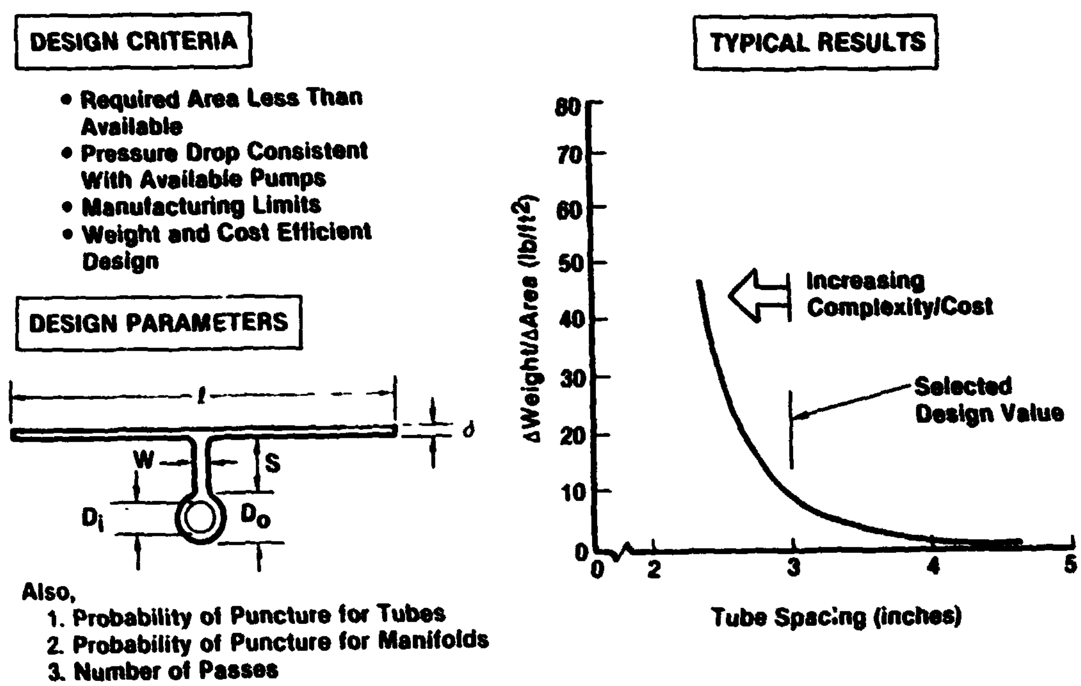


Figure 5.8.3-1 Pallet Radiator Design Optimization

The resulting radiator panel design is shown in Figure 5.8.3-2. Each radiator loop flows through two panels in series, each panel has four passes. Tube inside diameter is 0.2 inch which represents the lower size limit which can be extruded without cost impacts. A tube wall thickness of 0.138 inch and a manifold wall thickness of 0.15 inch results in a probability of no meteoroid penetration of 0.99 for one year. Other dimensions shown on the extrusion represent a compromise between low weight, performance and manufacturing ease.

As shown in the figure, the tubes make four passes per panel. All tubes are not shown for simplicity, so based on panel width and four-inch tube

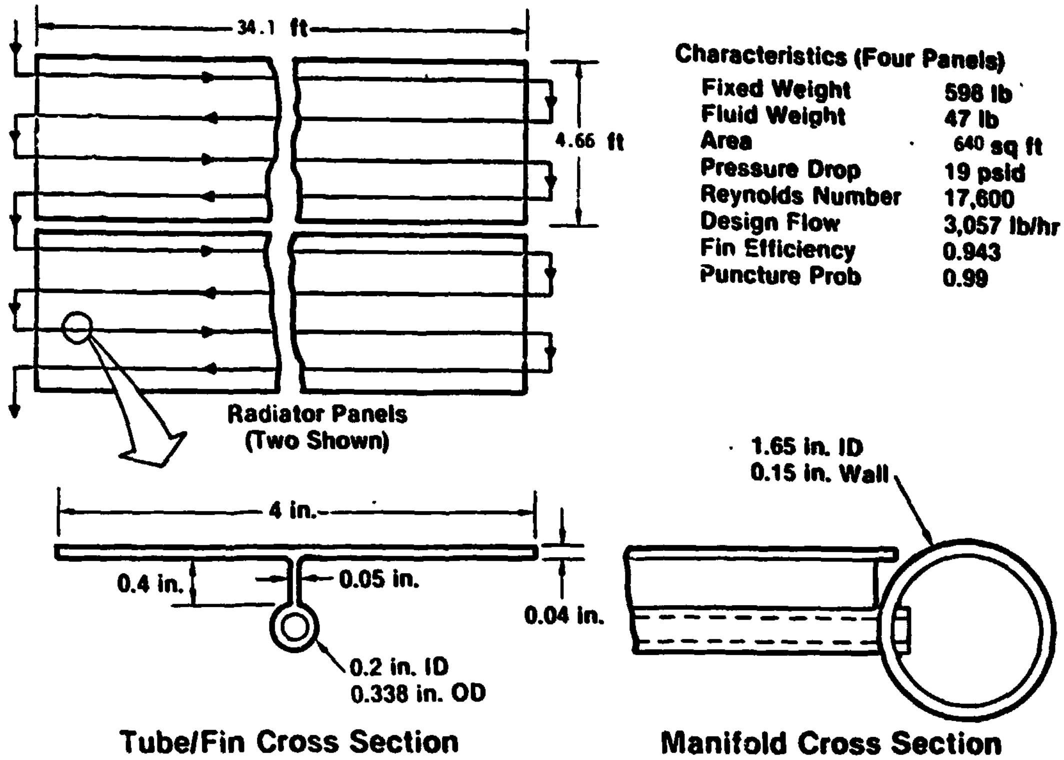


Figure 5.8.3-2 Selected Platform Radiator Details

spacing, each pass consists of four tubes in parallel. This tube geometry results in low fluid to fin temperature drop with a reasonable pressure drop, 19 psia.

The probability of meteoroid puncture of 0.99 includes effects of both manifolds and tubes. The optimum ratio of shielding in terms of expected penetrations per unit area time between manifolds and tubes is about 25 to 1 since vulnerable area is much smaller for manifolds.

Approximately 640 square feet of radiator area is available on the standoff section. Figure 5.8.3-3 shows the performance ot this radiator for various orientations and beta angles.

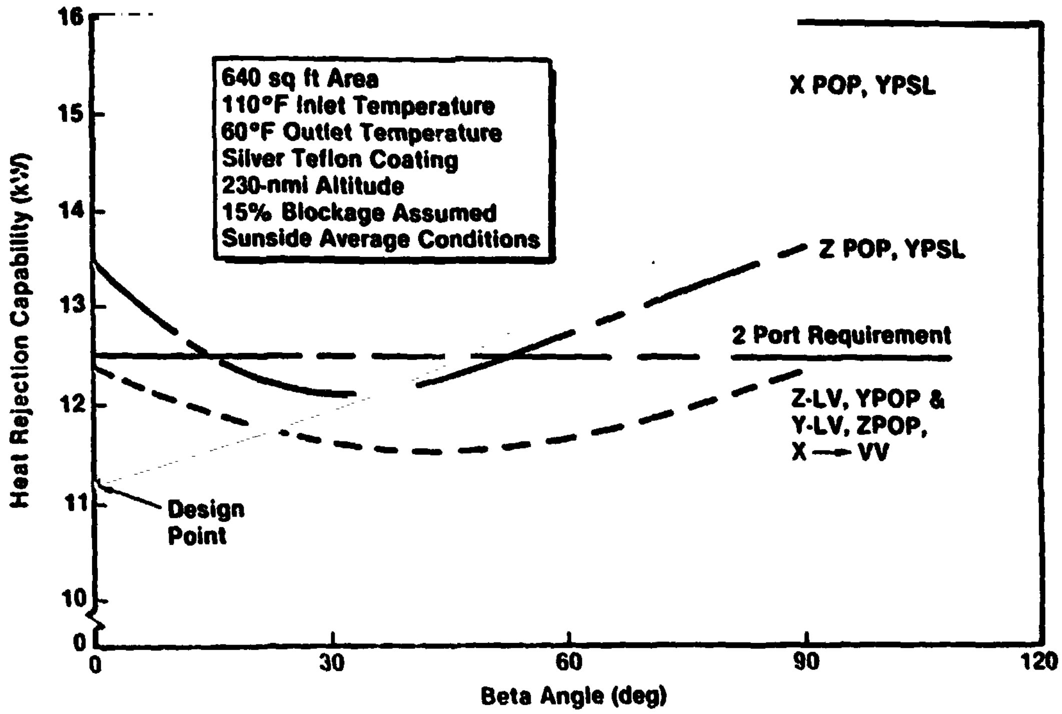


Figure 5.8.3-3 Platform Standoff Radiator Heat Rejection Capability

The selected design point is the worst case and amounts to 11.2 kW for 0° beta and X-POP, Y-PSL orientation. It can be seen that performance improves for other conditions.

A degraded silver teflon coating identical to that used on the Orbiter radiators was assumed. This is primarily a solar coating due to its solar absorptivity of 0.1 for a degraded condition. Since some of the radiator panels get very little solar impingement and albedo, use of a high emissivity coating may improve performance.

The data shown in the figure is for sun side conditions; performance will improve on the shade side of the orbit.

The platform centralized radiator concept is shown schematically in Figure 5.8.3-4 for cross arm configuration. Heat rejection is accomplished by the Power System radiator and by a separate platform radiator located in parallel. Two separate fluid loops are provided; each services half of the ports. The cross arm configuration is shown wherein each loop services a separate arm. Each loop flows 3410 lb/hr of Freon 21 which is in the design range for existing Orbiter pump units. Pressure drops in the loop are also compatible with existing pumps.

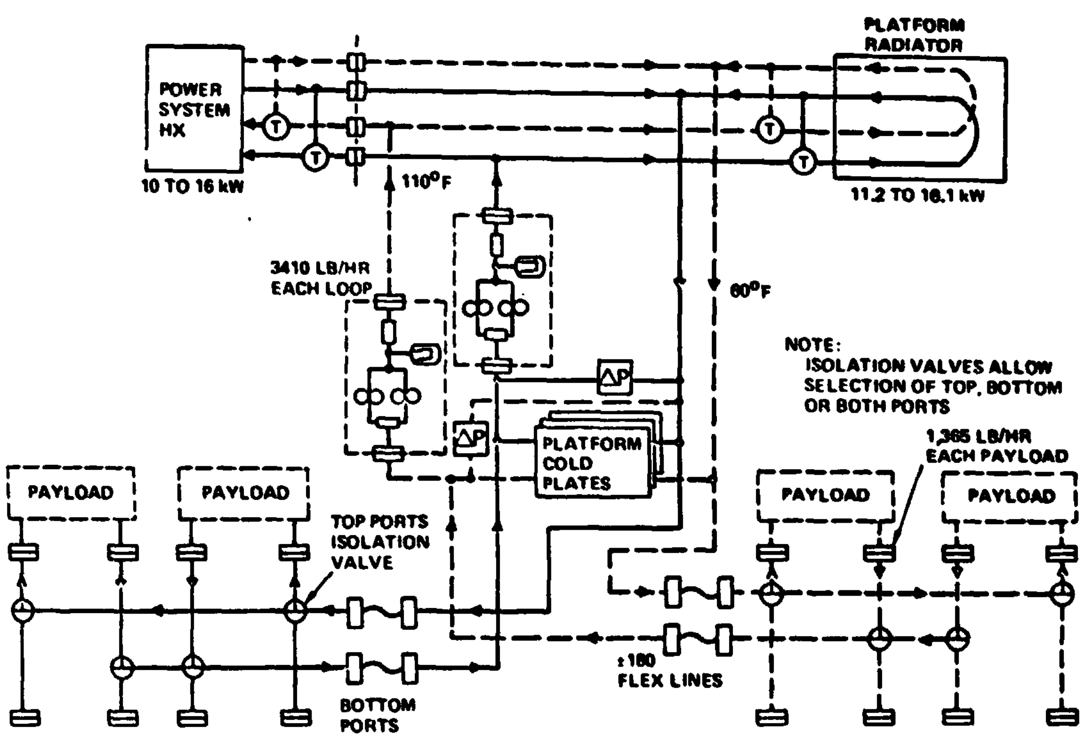


Figure 5.8.3-4 Platform Thermal Control Centralized Radiator Concept

Platform cold plates are located in parallel with the payloads so that platform heat loads do not perturbate payloads and ensures a 60°F fluid supply to payloads.

Fluid is directed to each arm through flex lines which allow the arms to rotate $\pm$180° relative to the center structure. Isolation valves opposite each port location allow Freon fluid to be directed to either or both top or bottom port locations. These valves also allow isolation of either port in the event of an excessive leak in a connector or payload.

Relatively constant pressure drop is maintained between supply and return fluid lines by the ΔP valves. Payload pressure drops will be trimmed by adding orifices in their loops to provide a predetermined pressure drop at the design flow. This will ensure a minimum imbalance when the payload compliment on the platform changes.

The design point for the platform radiators calls for an inlet temperature of 110°F and an outlet of 60°F. Many types of experiment hardware can tolerate higher temperatures and this improves the performance of the platform radiator. Figure 5.8.3-5 shows the effect of off design point higher temperatures.

Since the Power System heat exchanger and platform radiator are in parallel, they will have the same inlet temperature. These two means of heat rejection, however, do not produce identical outlet temperatures at off design point conditions. The Power System will provide 10-16 kW cooling, at 25 kW power output, dependent upon beta angle and orientation. As the temperature increases more cooling is not expected because the control logic limits Power System loop temperature. The platform radiator, however, will provide more cooling as temperatures rise as shown in the figures.

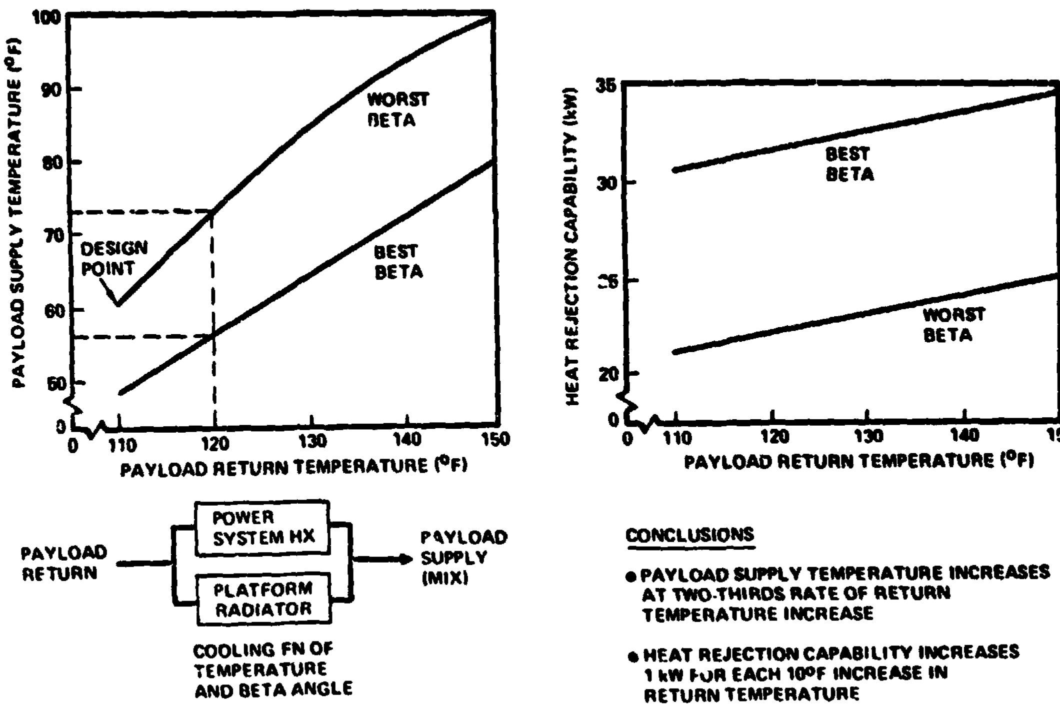
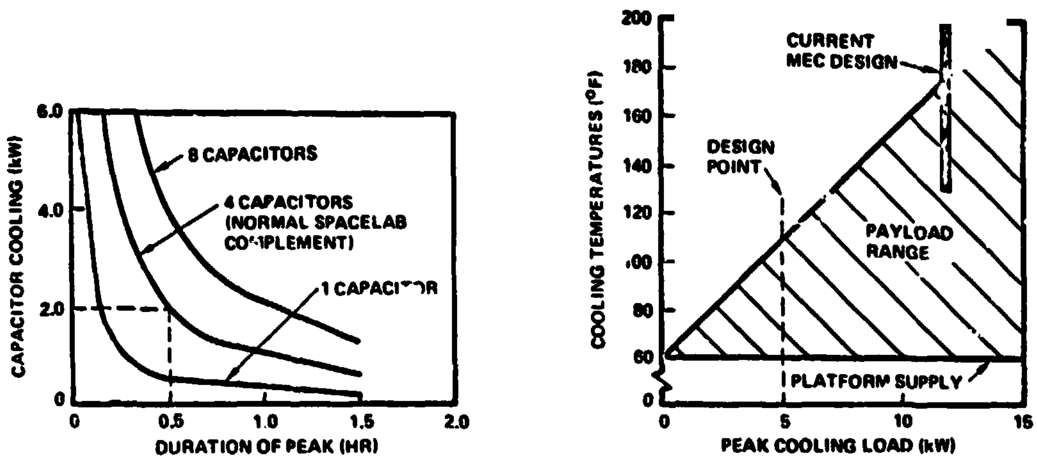


Figure 5.8.3-5 Thermal Control Subsystem Off Design Point Performance Platform Plus Power System Radiators

Conclusions of the analysis show that because of higher radiator performance, the payload supply temperature only increases at two-thirds the rate at which the payload return increases. This corresponds to an increase of 1 kW for each 10°F by which the payload return fluid increases in temperature. Therefore, for high power payloads without stringent temperature limits, platform available cooling increases above the design point.

Figure 5.8.3-6 presents two approaches to providing cooling to platform accommodated payloads during peak loads above 5 kW. The method selected will depend upon the equipment temperature limits and peak cooling magnitude and duration.



Peak Cooling With Thermal Capacitors
- Time Limited
- Requires Recovery Time
- Costly for Large Energy Storage

Peak Cooling by Allowing Elevated Temperatures
- No Time Limit
- High Temperatures
- Capacity Dependent Upon Total Cooling Load

Figure 5.P.3-6 Platform Accommodation of Peak Cooling Loads

Performance characteristics for peak cooling with thermal capacitors is given on the left side of the figure. A Spacelab type design is assumed where a phase change material would be encapsulated in a cold plate type design. The capacitors are mounted between experiment equipment and cold plates. During peak power levels the material in the capacitors melt and absorb heat equal to the latent heat of fusion. The figure shows the number of capacitors required for various power and duration conditions.

A drawback of the thermal capacitor approach is that before a peak occurs a time period at reduced experiment power is required so that the phase chang material becomes frozen. Once a peak occurs the capacitors can provide cooling for a limited time, until the phase change material is entirely melted.

A less costly method which is not time limited is shown on the right of the figure. This approach merely lets the payload outlet temperature rise as the

peak cooling load increases. Most experiment equipment can withstand the temperatures higher than the 110°F design point. Superimposed on the figure are the current design conditions for the Material Experiment Carrier which is a typical payload requiring peak cooling. This payload operated between 131 and 199°F. As can be seen from the figure, the Platform would provide cooler temperatures, 60 to 175°F.

The experimenter will decide upon the most appropriate method for peak cooling based on his equipment needs.

5.8.4 Conclusions and Comments

A centralized radiator concept has been selected and detailed which represents a weight and cost efficient design. The selected design was a result of numerous trade studies which compared the design options and selected optimum values of design parameters. The resultant design locates a centralized radiator concept on the platform standoff structure and augments the Power System radiator to provide a minimum of 5 kW cooling to each payload port. The concept has dual loops; each provides cooling to half of the platform mounted payloads in the cross arm configuration. On the trail arm configuration flying in the X-POP and Y-PSL, a separate trail arm radiator is provided to avoid a continuously rotating fluid gimbal.

As an example of platform accommodation of payloads, a sample case was evaluated which was the A-10 case (see Figure 5.8.4-1). This is a 400 km altitude at a 57° inclination for late 1987. Environment temperatures in terms of sink temperature and power level are given. These temperatures give some indication of the amount of heat lost directly to the environment. The material processing and anti-earth pointing payloads see cold environments and some of the electrical power is likely to pass directly to space. Earth

Payload	Pointing Requirement	Environment Temperature[2] (°F)	Power (kW)
EO-1	Solar[1]	0	1.64
HE-1	Anti-Earth	−130	1.39
HE-3	Anti-Earth	−130	1.36
ER-SAR	≈ Earth	−60 to 0	$\boxed{3.66}$
SMR-FP	Earth	0	1.66
SP-1	Solar	0	2.7
SMIP-3	Solar	0	$\boxed{3.78}$
MP-2	None	−130	$\boxed{5.86}$

1) Mounted on Solar Array
2) Average Sun Side — Silver Teflon Coating

Figure 5.8.4-1 Heat Rejection Requirements for A-10 Case

and solar viewers see a warmer environment and it is believed that the bulk of the electrical power must be removed by the fluid loop. The material processing payload is expected to operate at a higher temperature which also enhances heat loss directly to space.

Upon examination of the power levels, which represent heat rejection with no heat loss directly to space, there are three payloads which are marginal regarding accommodation by a pallet radiator concept. These are shown boxed in the power column. Only with a 30 to 50% heat loss to space could these loads be rejected with nominal temperatures of 60 to 110°F.

The centralized concept can accommodate all payloads without difficulty except for material processing which requires a slight temperature increase, increased flow rate or a small heat loss directly to space.

5.9 MANNED SUPPORT MODULE (MSM)

5.9.1 Introduction

Some designs of life science and materials processing payloads are expected to require pressurized modules. Available data was examined to identify platform design drivers for these types of payloads.

Conclusions to the study show that power requirements are higher for payloads housed in pressurized modules as compared to other payload types (see Figure 5.9.1-1). Additionally, cooling temperatures are lower due to crew of life science specimen needs.

ISSUES STUDIED

- **Life Science and Materials Processing Requirements**
- **Platform Design Drivers**

CONCLUSIONS

- **10 kW Electrical Power for Life Science; More Needed for Material Processing**
- **40°F Cooling Fluid Required for Life Science Payloads**
- **Heat Rejection Equals Electrical Power Plus Metabolic and Chemical**
- **Data Management Requirements Not Design Drivers**
- **Low G Levels Restrict CMG Torque, Attitude Rates and Slew Rates and Orbit Keeping Accelerations**

Figure 5.9.1-1 Platform Accommodation of Pressurized Modules

A review of data management requirements indicate that these payloads are not design drivers. However, the low g requirements are expected to impact the design of the attitude control subsystem and influence operational procedures.

5.9.2 Requirements and Provisions

Figure 5.9.2-1 highlights the design requirements for payloads housed in a pressurized module. Life sciences will require a minimum of about 10 kW electrical power and this will grow to 20 kW in the 1989 era. Material processing will have higher power requirements.

Requirement	Amount	Provision
Electrical Power	10 kW L/S >10 kW Materials Processing	Central Port Provision for >10 kW
Thermal Control	40°F Cooling	Platform Provision for 40°F Control or Pressurized Module Radiator and 40°F Control
Data Management	1mbps for L/S; 0.1 kbps Uplink 30 kbps Downlink 720 kbps Imaging	No Special Provision — Not a Design Driver
Attitude Control	10^{-4}g L/S 10^{-5}g Material Processing	Extended Duration Between Orbit Keeping Burns. Limit CMG Torques, Attitude Rates and Slew Rates. <0.1° per sec Rotation Rate Limits. Locate Modules Near Center of Gravity
Operation	Pressurized Link with Orbiter	Platform Support Module, EVA Crew Transfer or Non-Spacelab Module Structure

Figure 5.9.2-1 Pressurized Module Requirements and Design Provisions

Cooling temperatures of 40°F will be required for pressurized modules to maintain cabin humidity and temperature. This is less than the 60°F currently provided by the Power System or platform. This lower temperature could be accommodated with a radiator located on the module surface.

Life science low g requirements of $10^{-4}g$ will normally not be exceeded in a module located near the center of gravity. However, orbit keeping burns can cause this level to be exceeded and these events will require scheduling. Material processing g levels are lower, $10^{-5}g$, and will impact the design of the attitude control subsystem.

Crew transfer is required between the Orbiter cabin and the pressurized modules. EVA is not an efficient means of doing this and so a direct pressurized link is preferred. A platform support module is recommended which allows docking with the Orbiter and other modules. This also allows use of the Spacelab structure which does not have multiple docking capability.

5.9.3 Assumptions and Design Requirements Details

The major design assumptions used in the study are listed in Table 5.9.3-1. The guidelines and assumptions were used to establish a common pressurized support module to interface the Power System and support berthed manned payloads.

The life sciences mission model used as representative for the purposes of this study, imposes severe requirements on a Manned Support Module (MSM) in the later phases of the program. The MSM is the berth to the Power System and provide berthing accommodations for a Life Sciences Laboratory Module and a habitability module, both of which remain permanently berthed throughout these phases of the mission. Ports must also be provided for Logistics modules and for berthing to the Orbiter.

The pressure and atmosphere of the MSM must be identical to the pressure and atmosphere of the other modules so that "shirtsleeve" translation between the various modules can be accomplished. The Power System is expected to

- **Operational Period Starts in 1987 for Life Sciences and 1988 for Materials Processing Laboratories**
- **235-nmi Orbital Altitude at 28.5° Inclination**
- **Ten-Year Life With On-Orbit Maintenance**
- **SASP Will Interface With the Orbiter, Life Science Laboratory, Materials Processing Laboratory, Habitability Module, Logistic Modules, and the Power Module**
- **NASA MOSC Will be Study Used as Guidelines for Habitability and Logistic Module Concepts**
- **Power Requirements, Module Sizes and Crew Sizes for Life Sciences Will be Based on NASA SASP Study Payload Element Descriptive Data Report, Dated July 1979**
- **Habitability Module Will Provide the Major Life Support Capability (Excluding Atmospheric Storage) for the Manned Systems Operations for the Shuttle Unattended Mode**
- **Initial Power Requirements for the Materials Processing Laboratory Will be Based on NASA Experiment Module II (R-4) Information. Newly Developed Data From NASA Will be Used to Refine SASP When Received**
- **Habitability and Logistic Module Concepts From MOSC Will be Used Also For the Developed Materials Processing Laboratory Concept**
- **NASA Referenced Power Module Defined in NASA PM-001 Will be Used as the Baseline Data for Comparisons**

Table 5.9.3-1 Design Assumptions for Manned Platform Study

provide power, thermal control, communications, and data transmission for all berthed modules. The MSM will provide the connecting link for these resources. In an earlier phase of the mission, before the Logistic Module is left by the Orbiter, the MSM may be used as a storage unit for atmospheric gases and other supplies needed to maintain the Life Science Laboratory and crew between Orbiter visits. Design requirements are listed in Table 5.9.3-2.

- THE MSM SHALL PROVIDE THE MEANS OF TRANSFER FROM THE SHIRTSLEEVE ENVIRONMENT OF THE ORBITER TO THE SHIRTSLEEVE ENVIRONMENT OF THE VARIOUS BERTHED MODULES SUCH AS: (1) LIFE SCIENCE LAB, (2) HABITABILITY MODULE, (3) MATERIALS PROCESSING LAB, (4) ONE OR TWO LOGISTICS AND MODULE AND THE SYSTEMS NECESSARY TO EFFECT SUCH A TRANSITION.

- PROVIDE CONNECTING LINK FOR POWER ACTIVE THERMAL CONTROL, COMMUNICATIONS, AND DATA TRANSMISSION BETWEEN THE POWER SYSTEM AND OTHER BERTHED MODULES AND/OR ORBITER.

- THE MSM TO SERVE AS A STORAGE UNIT FOR ATMOSPHERIC GASES AND OTHER SUPPLIES AND EXPENDABLES NEEDED FOR LABORATORY OPERATION.

- THE MSM TO PROVIDE THE STRUCTURAL INTERFACE BETWEEN THE POWER SYSTEM/ SASP AND THE ORBITER.

- THE EXTERNAL DIMENSIONS OF THE MSM SHALL BE CONTAINED DURING LAUNCH WITHIN A DYNAMIC ENVELOPE OF 4.6M (15 FT) DIAMETER AND 18.25M (60 FT) LONG.

- THE STRUCTURE SHALL BE DESIGNED FOR AN OXYGEN/NITROGEN MIXTURE @ 14.7 PSI MAX INTERNAL PRESSURE.

- BERTHING PROVISIONS INTERFACING WITH THE ORBITER OR ORBITER ELEMENTS SHALL INCORPORATE A PASSIVE MECHANISM COMPATIBLE WITH THE ORBITER BERTHING SYSTEM.

- ALL BERTHING PORTS AND HATCHES SHALL BE SIZED FOR A MINIMUM 40.0 INCH OPENING SIMILAR TO THE ORBITER "D" SHAPED AIRLOCK HATCH.

- EACH PRESSURE HATCH SHALL HAVE A WINDOW.

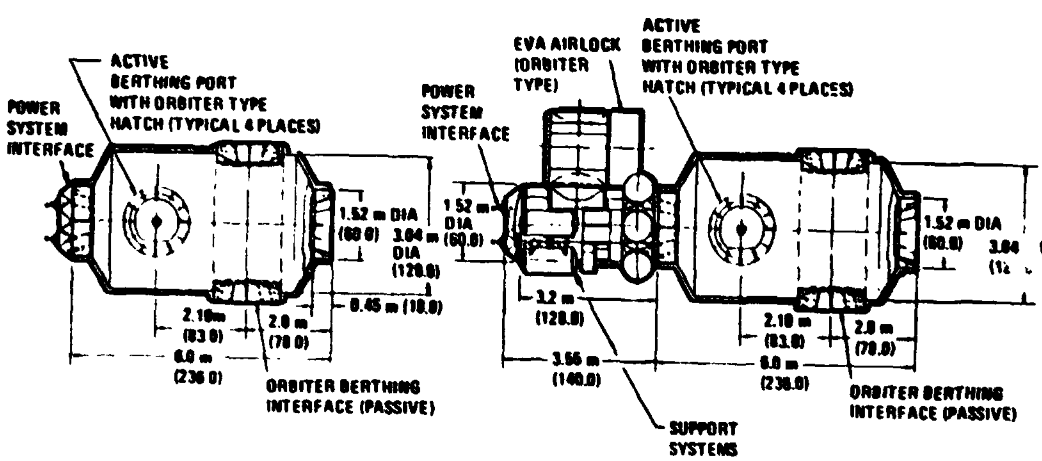
- INTERNAL COMMUNICATIONS (DUPLEX VOICE, CAUTION AND WARNING TONES, AND VIDEO) SHALL BE PROVIDED WITHIN THE MSM AND AT ALL ACTIVE BERTHING PORTS.

- UTILITIES INTERFACING CONNECTIONS BETWEEN BERTHED ELEMENTS SHALL BE LOCATED WITHIN THE PRESSURIZED VOLUME.

Table 5.9.3-2 Manned Support Module Design Requirements

5.9.4 Preliminary Manned Support Module Concepts

The preliminary manned support modules are shown in Figure 5.9.4-1. During the study, five concepts were evaluated. Concept 1 is a 3.0m dia x 6.0m long structural element configured to provide the structural interface between the Orbiter and Power System plus four (4) pressurized modules. Concept 1 does not contain subsystem elements except those required to provide the link between services and crew safety. The modules only function is to provide a shirtsleeve translation capability between modules and receives its environment from external sources. Concept 5 shown, includes all services necessary to service berthed modules both manned and unmanned, including EVA provisions, atmospheric supply, and subsystem status equipment. The other three concepts have features in between Concept 1 and Concept 5.



CONCEPT 1

CONCEPT 5

Figure 5.9.4-1 Manned Support Module Options

5.9.5 Baseline Manned Support Module Configuration

The Baseline Manned Support Module shown in Figure 5.9.5-1 is configured to support pressurized Life Science and Materials Processing experiments in a manned sortie mode or in an automatic free-flying mode of operation. In addition, the module configuration shown permits growth to a manned free-flying scientific laboratory. The concept provides: (1) passive berthing interface for Orbiter, (2) active berthing interfaces to accommodate four payload modules, (3) passive interface with Power System or SASP, (4) interface connections for utility support, air exchange, and water transfer, (5) emergency vent capability, (6) Power System status panel, (7) communication/data processing interface equipment, (8) atmosphere supply and pressurization tanks, (9) EVA airlock and support equipment, (10) thermal control interface equipment, (11) module ventilation system, (12) module internal lighting, and (13) emergency life support pallet.

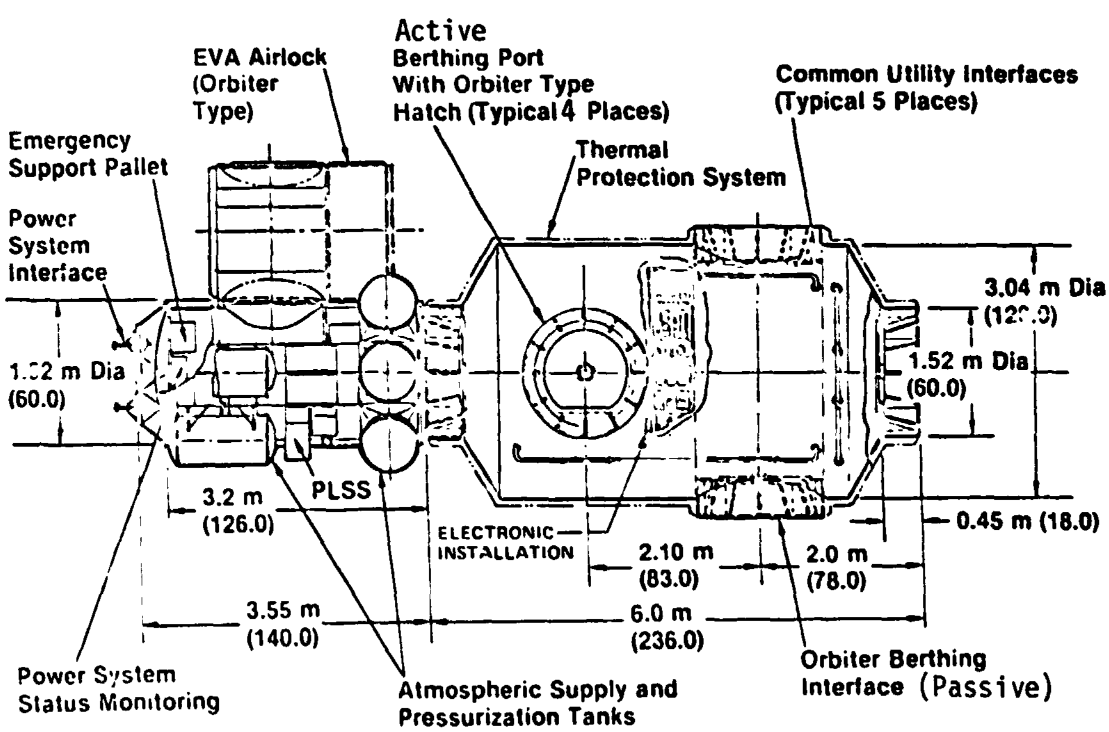


Figure 5.9.5-1 Preliminary Manned Platform Module - Concept 5

5.9.6 Manned Support Module - Communications/Data Processing System

The manned support module communications and data subsystem shown in Figure 5.9.6-1 provides for control of, and data acquisition from, support module subsystems via the Power System communications equipment and data bus. Crew members can monitor Power System, Support Module, and experiment status and enter commands with the CRT/keyboard equipment. Other crew support capabilities include caution and warning display and annunciation, physiological monitoring, closed-circuit television, and voice communications. Subsystem components can be identical to, or derived from, Spacelab and Orbiter communication and data equipment.

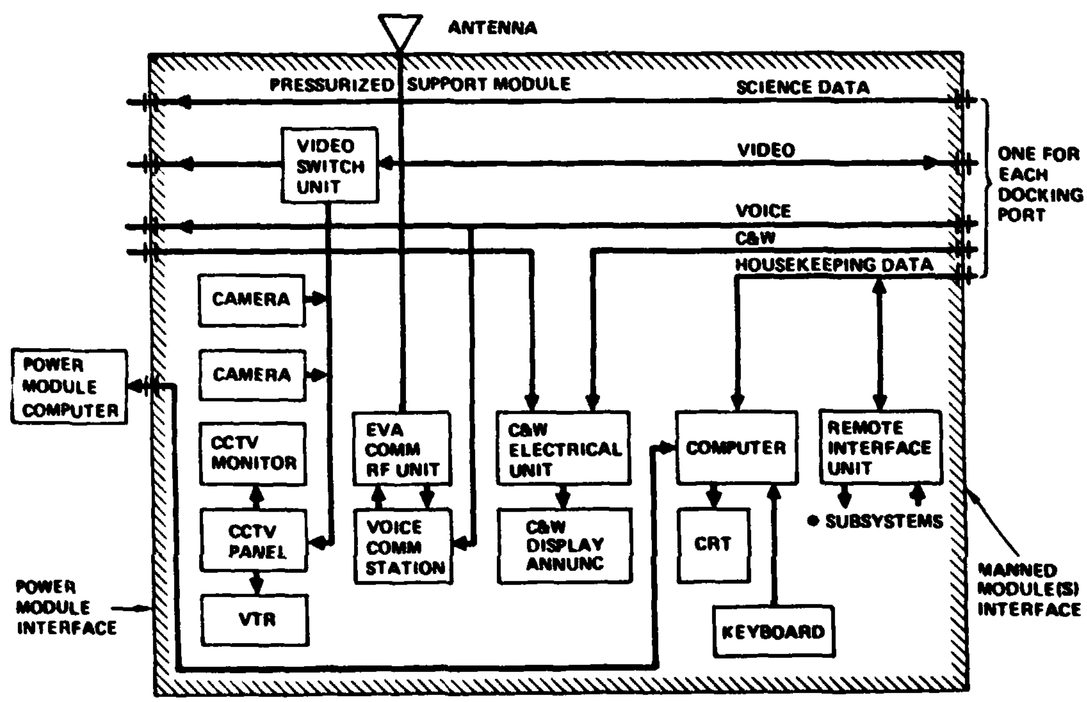


Figure 5.9.6-1 Manned Support Module Communications/Data Processing System

5.9.7 Power Distribution System

The support module power distribution system shown in Figure 5.9.7-1 provides the electrical Power System interface between the Power System berthed Orbiter, and payloads. Power System status assessment capability is also provided. The manned berthed payloads will be provided 30 VDC, 125-180 VDC unregulated/120 VDC optional regulated, and 115/200 VAC 400 Hz of electrical power. The preliminary distribution system was sized to accommodate the Materials Processing configuration because it required the highest power level. This permitted the Support Module to accommodate payloads that required up to 100 to 125 kW of power as well as the lower power users. A major amount of the materials processing furnace heating was considered to be provided by unregulated 125-180 VDC. The support module lighting system, thermal control system equipment, communications/data processing system will require up to 2 kW of AC/DC power. The emergency mode of operation of the Support Module System requires approximately 1.1 kW.

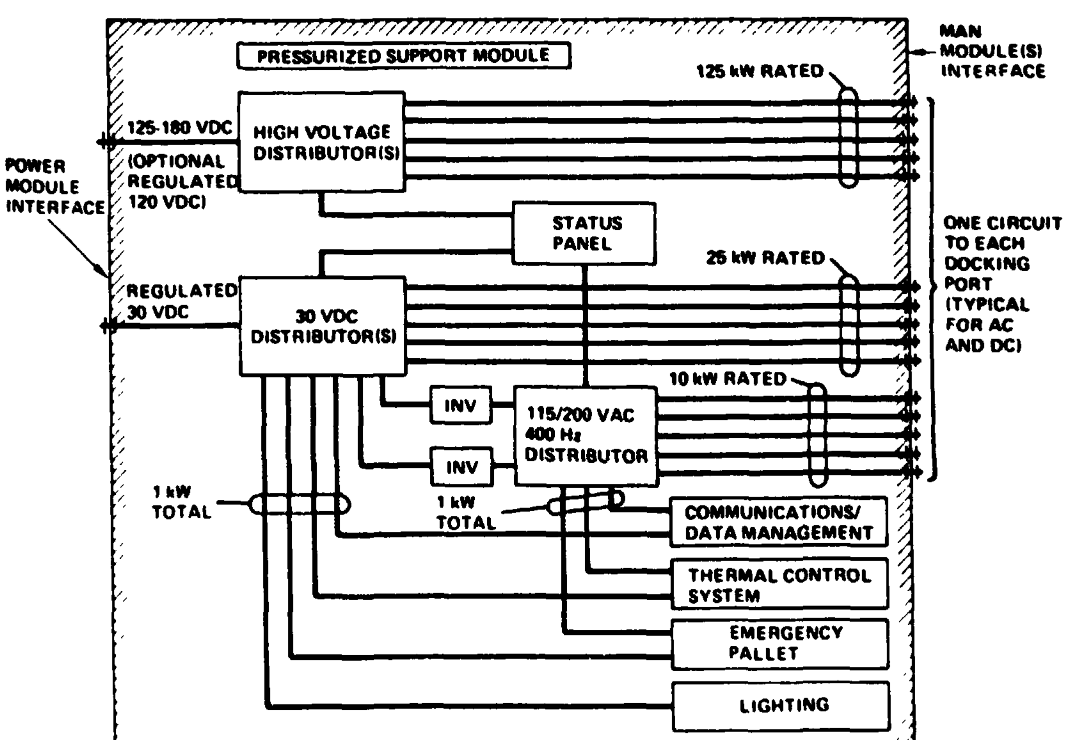


Figure 5.9.7-1 Manned Support Module Power Distribution System

5.9.8 Thermal and Environmental Control System and Emergency Pallet

The baseline support module thermal control and environmental control system, shown in Figure 5.9.8-1 provides (1) atmospheric control and pressurization gases for the docked manned payloads, airlock operation and for the Support Module, (2) air temperature control and ventilation for the Support Module, (3) cooling of support module equipment, (4) emergency venting capability, (5) emergency pallet for crew support, and (6) thermal control interface equipment for the supply of cooled fluid to the Orbiter and payload interface heat exchangers from the Power System centralized system. Figure 5.9.8-1a presents the NASA referenced ower System centralized thermal control system heat rejection capability versus the life science laboratory requirements for build-up and growth periods. For the example, an autonomous module surface radiator is required added to the initial habitability module (or equivalent) unless the capability of the Power System centralized radiator is increased. Additionally, laboratory module mounted radiators (or equivalent) are require as shown as growth continues up to 39 kW. The Power System capability would have to be increased to nearly 40 kW to meet the life science laboratory growth requirements for the developed profile.

Another approach would involve requesting the centralized Power System radiator to be enlarged. More detailed interface and impact trades are required to decide on the advisability of this latter approach.

The emergency pallet provides the crew up to 180 hours of support capability. The unit provides temperature control, humidity control, CO_2 control, food, water and waste management capability. The emergency pallet is similar to that of the NASA MOSC concept. A portable life support system (PLSS) was provided for spacesuit support. Two spacesuits are located in the airlock for normal EVA.

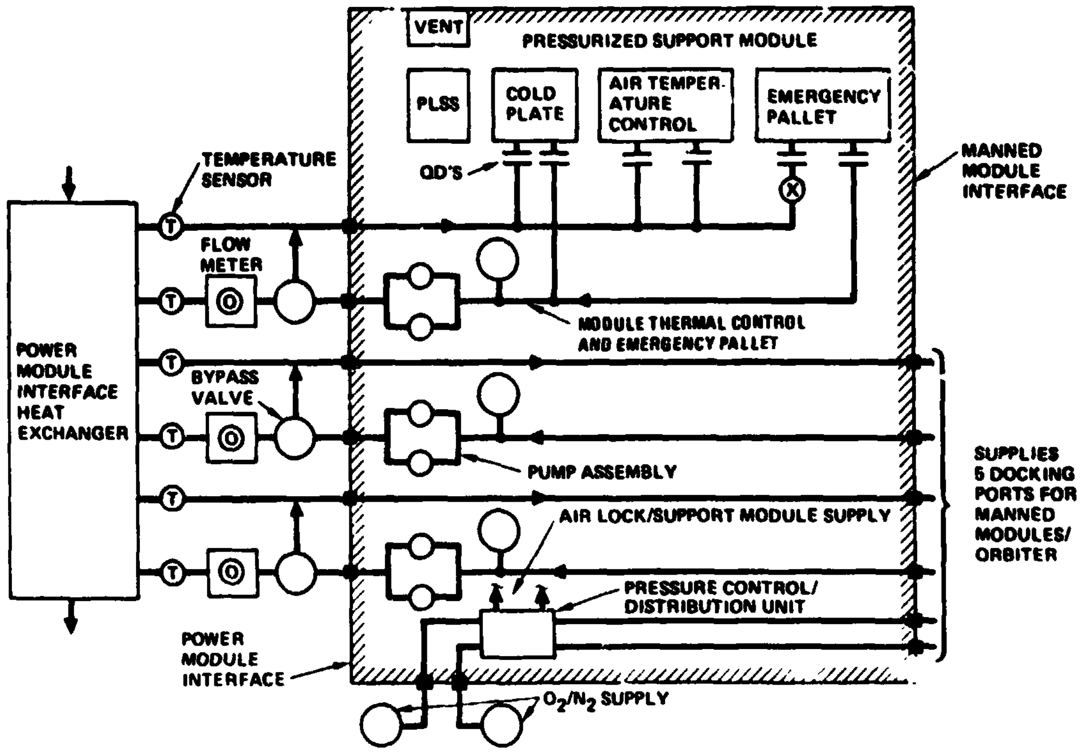


Figure 5.9.8-1 Manned Support Module Thermal and Environmental Control System and Emergency Pallet

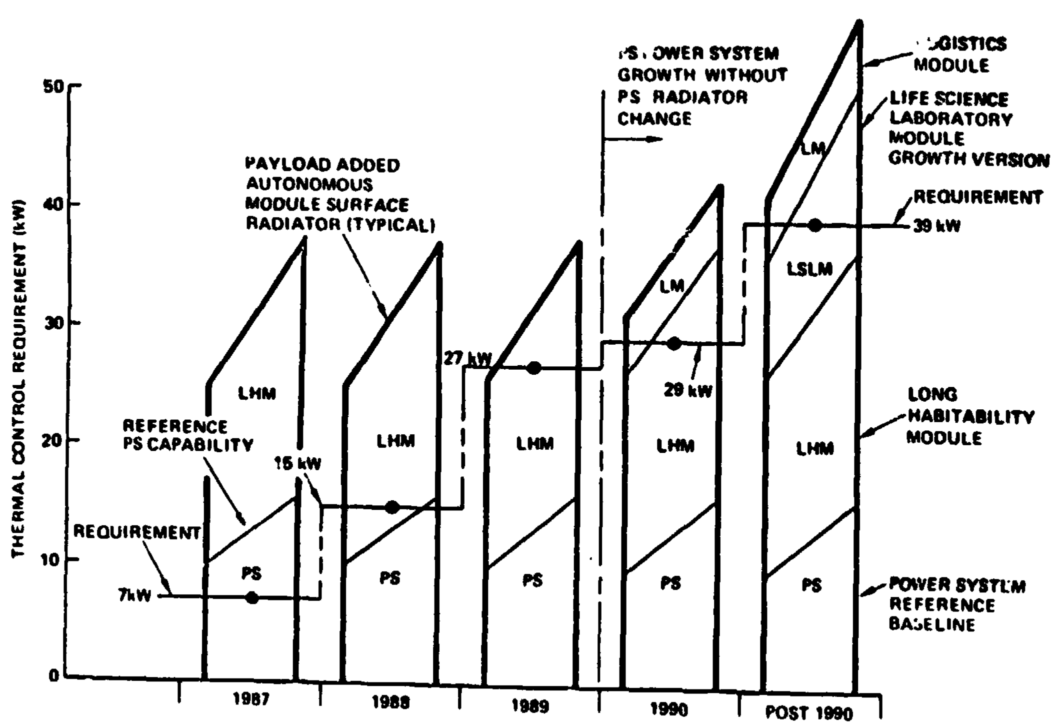


Figure 5.9.8-1a Life Science Thermal Control System Buildup with Reference Power System Capability - Concept A

Each docking port interface plate is provided two sets of interface Q.D.'s for thermal control. One set is provided for backup. Nitrogen and oxygen lines are also provided at the support module interface plate at each docking port.

5.9.9 Manned Support Module Major Interfaces

The manned support module major interfaces are shown on Figure 5.9.9-1. A common berthing interface was developed that will accommodate the Life Science Laboratory Module, Logistics Module, and Orbiter at any of five berthing port positions. The individual interfaces required by each module is shown on the left side of the figure. The Power System-to-support module is the only different interface as shown. The common berthing port interface configuration that is recommended is shown on the right side of the figure.

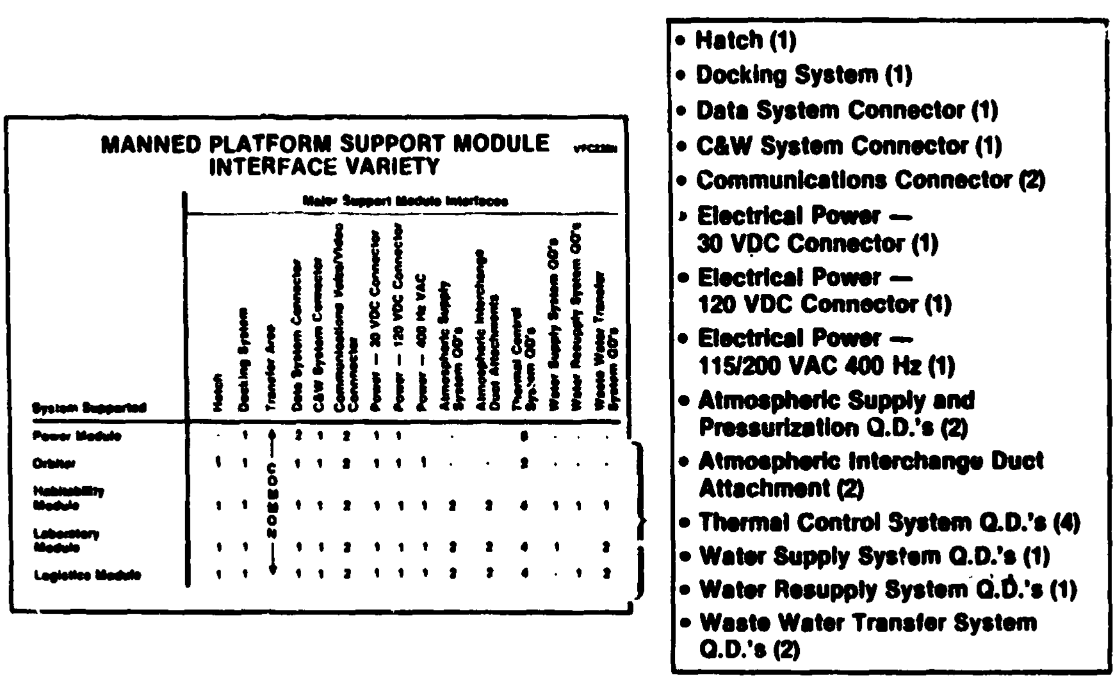


Figure 5.9.9-1 Manned Platform Support Module Major Interfaces

The interfaces were developed considering that (1) the Habitability Module contained the central water supply for all modules (except emergency water), (2) resupply of water from the Logistics Module was transferred to the Habitability Module, (3) Habitability Module systems reprocessed waste water, and (4) the Habitability Module provided the major CO_2 removal function for all of berthed modules.

5.9.10 Early Multi-Mode Platform/Laboratory

An early multi-mode platform, shown in Figure 5.9.10-1 represents a compact, low-cost, platform/laboratory with limited experiment capabilities. This Spacelab derived Life Science/Materials Processing lab, with a Manned Support Module (MSM), is berthed to the First Order SASP. Payloads attached to the Power System are serviced by an EVA crewman, in support of the processing laboratory test requirements, during the sortie mode. As a free-flyer, the MSM provides all subsystem support required to complete the experiment program until the next Orbiter visit. Additional life science laboratory or materials processing modules can be added at the other ports.

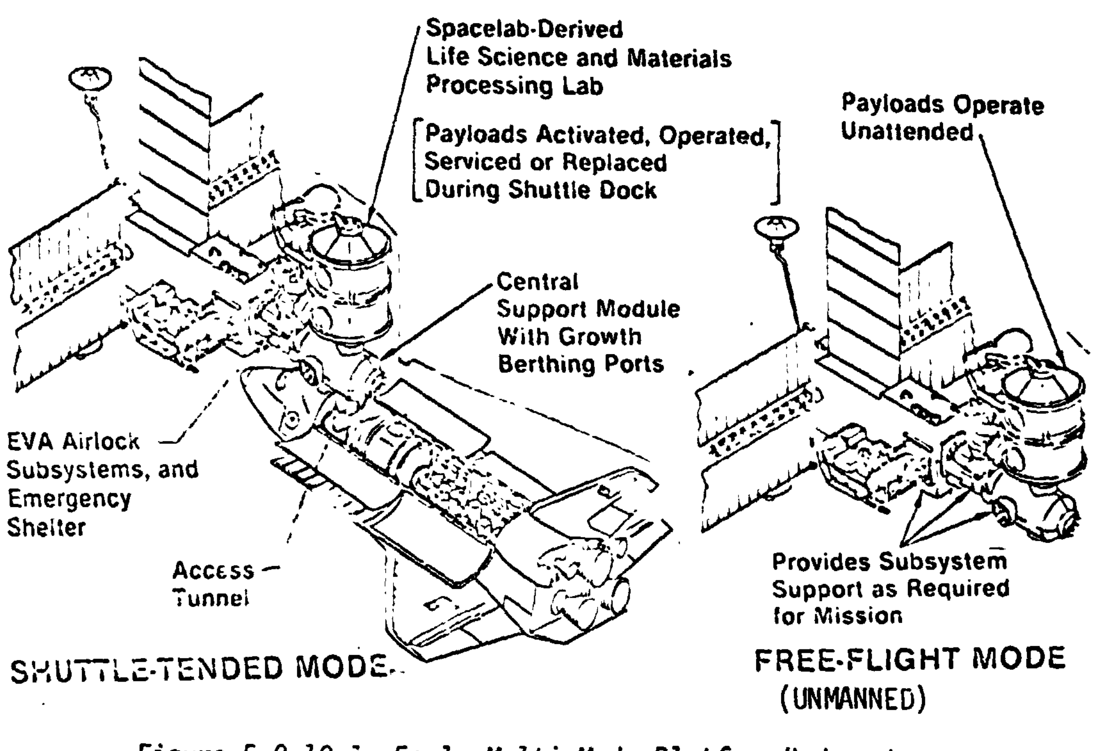


Figure 5.9.10-1 Early Multi-Mode Platform/Laboratory

5.10 PLATFORM WEIGHTS

The weights presented in Table 5.10-1 were derived from subsystem equipment lists prepared with allowances added for secondary elements such as attaching parts, fittings, and support structures. Based on the current level of the platforms definition, a 25% contingency was added to achieve a projected estimate of what the hardware would weigh when developed.

The First Order Platform weighs 3643 pounds. The Second Order Platform weighs 13,054 pounds which includes the basic Second Order Platform weighing 9811 pounds plus the First Order Platform (3641 lbs) less the smaller adapter (400 lbs). Addition of the trailing arm would increase the weight by 2551 pounds and the deployable arms (2) would add 5214 pounds.

SUBSYSTEM	1ST ORDER	2ND ORDER		
		BASIC CROSS ARMS AND STANDOFF	TRAILING ARM	DEPLOYABLE ARMS (2)
STRUCTURE/MECHANICAL	2206	4327	1091	3088
BERTHING PROVISIONS	1125	1566	816	1320
SUBSYSTEM MODULE	-	469	-	-
TRUSS AND SUPPORTS	681	1332	275	1768
ADAPTERS	400	960	-	-
THERMAL CONTROL	165	1287	631	165
RADIATORS	-	600	300	-
COLD PLATE	-	125	65	-
CONTROL AND LINES	165	267	118	165
FLUID	-	295	148	-
AVIONICS	60	390	71	142
ATTITUDE CONTROL	-	470	-	-
POWER DISTRIBUTION AND CONTROL	483	1375	248	776
DISTRIBUTORS	318	165	54	-
CONTROLS	-	46	-	-
CABLES	165	1164	194	776
SUBTOTAL - LBS	2914	7849	2041	4147
CONTINGENCY (25%)	730	1962	510	1043
TOTAL PROJECTED WEIGHT - LBS	3643	9811	2551	5214

Table 5.10-1 Platform Weight Summary

Section 6
OPERATIONS
(Task 6)

6.1 ON-ORBIT OPERATIONS

6.1.1 Requirements

The major SASP on-orbit operational requirements are shown in Table 6.1.1-1. These requirements must be satisfied for all platform configurations. Three major assembly options are available to the platform designers; (1) berthed Orbiter using Orbiter baseline equipment only, (2) berthed Orbiter using special handling equipment, and (3) remote assembly using a TRS type vehicle. Each candidate platform was analyzed to identify required support equipment necessary to comply to the basic operational requirements. On-orbit assembly confined to use of baseline equipment restricted platform configuration and growth potential, therefore, was not considered a viable candidate. Remote assembly using a TRS type vehicle and EVA becomes a complex control problem involving greater crew risk. Since a technology advancement would be required to achieve controlled berthing, the system was not considered a candidate. Addition of special handling equipment, such as a deployable berthing system, is the favored concept.

- PLATFORM TO BE REMOVABLE FROM CARGO BAY USING RMS
- PLATFORM TO BE AUTOMATICALLY DEPLOYED AND VERIFIED
- PLATFORM TO BE DESIGNED CAPABLE OF ON-ORBIT RECONFIGURATION
- INSTRUMENT CARRIERS TO BE INSTALLED, REMOVED OR EXCHANGED USING SINGLE RMS
- BERTHING PROVISIONS TO BE INCORPORATED TO PLACE ALL PAYLOADS WITHIN RMS CAPABILITY
- ALL PAYLOAD CARRIERS TO BE EQUIPPED WITH UNIVERSAL BERTHING/UMBILICAL MECHANISM AND STANDARD RMS GRAPPLE FITTING
- PLATFORM ORBIT-KEEPING FUNCTION TO BE PROVIDED BY POWER SYSTEM AND/OR ORBITER AS REQUIRED
- PERIODIC SERVICING AND MAINTENANCE TO BE PERFORMED BY EVA CREWMAN WITH ASSISTANCE OF RMS
- MAINTAIN A POSITIVE ATTACHMENT BETWEEN ORBITER AND SASP DURING ASSEMBLY AND/OR SERVICING OPERATIONS

Table 6.1.1-1 SASP On-Orbit Operational Requirements

6.1.2 SASP Operational Methods

The four basic operational categories are shown in Table 6.1.2-1. The primary requirement of any operational method is to access all payload attach points on any given platform. This is true for initial attachment, payload removal and/or exchange, and for experiment maintenance. Four possible solutions are identified. Early evaluations indicated that the RMS would meet all of the basic requirements with multiple berthing provisions incorporated at discrete locations on the Platform, enabling the Orbiter to be positioned, as necessary, to maximize the RMS capability. Recent program requirements limit the Orbiter to a single rendezvous/berthing operation, thereby requiring that all payload locations be accessible from a single position. As a result, the current, favored operational method is using a single RMS with rotating and telescoping berthing mechanisms. The preferred mechanisms are defined in Sections 4 and 5 of this report.

REQUIREMENTS	METHODS
• EXPERIMENT INSTALLATION, REMOVAL, AND MAINTENANCE	• SINGLE RMS WITH ROTATING BERTHING MECHANISM • SINGLE RMS WITH MULTIPLE ORBITER BERTHING PROVISIONS • MULTIPLE RMS'S WITH DOCKING MAST • TRS/SERVICER
• CONSUMABLE RESUPPLY AND EXPERIMENT RECONFIGURATION (FILM, CRYOGENICS, HIGH-PRESSURE GAS, SAMPLES, LENS AND SENSORS, AND T.. 'ES)	• EVA WITH RMS • EVA WITH MMU AND RMS • EVA WITH MRWS • TRS/SERVICER
• PAYLOAD HANDLING	• STD END EFFECTOR/GRAPPLE FIXTURE • SPECIAL DESIGNED GRAPPLE FIXTURE
• VISIBILITY OF PLATFORM/PAYLOAD ATTACHMENT	• DIRECT VISION WITH EVA • RMS TV • TV AT ATTACH POINT • PLATFORM MOUNTED TV'S • GUIDE LIGHT • SOFTWARE PROGRAM WITH SPECIAL END EFFECTOR

Table 6.1.2-1 SASP Operational Methods

Consumable resupply and experiment reconfiguration is an important part of the platform operations. Various methods are possible and the selected method will depend on the platform configuration and handling method employed. An EVA crewman equipped with the MMU will have increased mobility to support the RMS operator and to transfer smaller items for experiment resupply and/or reconfiguration.

A standard handling method will be required to remove/replace payloads in the Orbiter cargo bay, and attach/remove payloads from the SASP. The RMS std end effector and grapple fixture were selected as the standard system.
A grapple fixture, as defined in the Space Shuttle System Payload Accommodations Handbook #JSC 07700, will be required on each payload package.

The payload/SASP berthing attach point will not be visible to the eye of the RMS operator attempting to position the payload. Therefore, some type of visual assistance will be required. The current favored concept is use of TV cameras mounted at each berthing port incorporated in the design of the active interface mechanism.

6.1.3 First Order Platform Orbital Operation

Payload port options, number of payloads to be accommodated, and the number of options available for loading selected experiments are listed in Table 6.1.3-1. Three Power System payload ports and one reserved parking port is the currently favored concept. It appears that this selection satisfies the viewing requirements with no impact on the Orbiter or payload systems, however, positioning payloads on the (+Y, -Y) ports of the First Order SASP requires the Power System be berthed at Orbiter Sta Xo 550. As shown in Figure 6.1.3-1, this position is necessary to enable the RMS to be deployed to a vertical position in order that it can be rotated 180° placing the end effector in the proper orientation. This forward position is accomplished by incorporation of a First Order Berthing Adapter. This adapter interfaces with the Orbiter Berthing System and the Power System and provides rotational capabilities at both interfaces. Each payload c.g., including a three-pallet payload can be assessed by the RMS with the Power System in this location. Access to the (+Y) port is not compatible with the RMS capability with PS in this position, without rotation about STA Xo 550 or Xo 633. Section A-A, shown on Figure 6.1.3-2, illustrates two methods of access to both the +X port and the (+Y) port. Pallet access options are shown in Table 6.1.3-2.

Maintaining the Power System/Orbiter orientation along the (X) axis requires the (+Y) payload be rotated as shown. The RMS may be able to access the

PAYLOAD PORT OPTIONS	COMMENTS
• 2 Payload Ports (+Z and +X) plus 2 Growth Options (± Y)	• MSFC Baseline • Limited to (2) Axis Simultaneous Viewing • Requires Remote Parking Provisions for Payload Exchange
• 3 Payload Ports (± Y and +X) plus 1 Reserved Port (+Z) √	• Currently Favored • Satisfies (3) Axis Simultaneous Viewing Reqmt • Provides Parking Space During Payload Exchange • No Additional Equipment Requirement
• 4 Payload Ports (± Y, +X, and +Z)	• Maximum Payload Accommodation • Requires Remote Parking Provision for Payload Exchange
LOADING OPTIONS √	
• Reserve +Z Port for Temporary Payload Parking	• Currently Favored • No Impact on Orbiter or Payload Systems • No Additional Equipment Required
• Second RMS on Orbiter	• Weight and Cost Penalty on Payload Systems
• Reserved Cargo Bay Space	• Sacrifices Valuable Cargo Bay Space (One Space Empty Up) • Possible Program Impact
• Orbiter Deployed Parking Platform	• Impact on Orbiter • Weight and Cost Penalty on Payload
• Power System Deployed Parking System • PS Mounted RMS • New Design Manipulator (MSFC Baseline)	• Extreme Cost Penalty • New Manipulator May Result in a Mini-RMS Design and Software Program

Table 6.1.3-1 Power System Payload Ports and First Order Loading Options

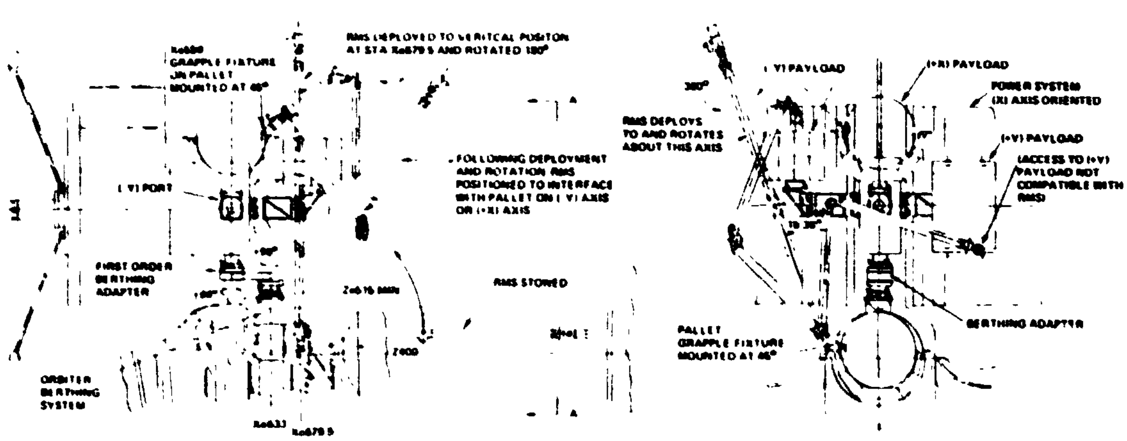


Figure 6.1.3-1 First Order Platform Orbital Operation/Pallet Access (-Y Pallet)

payload without interference with the X axis payload, however, the angle of deployment may exceed the angular motion of the RMS and will make it difficult to translate the payload in a straight line to disengage the interface mechanism. If a three pallet payload was berthed on the (+Y) port, it might not have been possible for the RMS to access the CG thereby adding an undesirable load on the RMS mechanism. Rotating the Power System to the Orbiter (+Y) axis as shown, enables the RMS to access the payloads, engage/disengage the interface and place in cargo bay with minimum obstruction. It appears desirable to employ both methods to access payloads, as a result, the rotational requirement was added to the First Order Berthing Adapter. In addition, the rotational characteristics of the RMS make it necessary to place the payload grapple fixture at a 45° angle as shown in Figures 6.1.3-1 and 6.1.3-2. This location minimizes impact on the payload configuration and enhances the RMS operation both in the cargo bay and on the Platform.

6.1.4 First Order Basic Second Order Platform Transition

The Basic Second Order Platform transition shown in Figure 6.1.4-1 assumes that the First Order Platform, with only three payloads, has been placed on orbit by previous Orbiter flight(s). Following the deployment and verification of the Orbiter berthing system, with first order berthing adapter, the First Order Platform is berthed to the Orbiter at the Power System (-Z) port. After interface verification, the RMS removes the (+X) payload and places it on the (+Z) parking port. The Second Order SASP is then removed from the cargo bay and positioned on the Power System (+X) parking port. The Second Order SASP is then removed from the cargo bay and positioned on the Power System (+X) port. With the RMS attached to the Second Order SASP the interfaces are verified. Following verification, the RMS is stowed and the structural cross-arms are deployed and each of the SASP subsystems are verified.

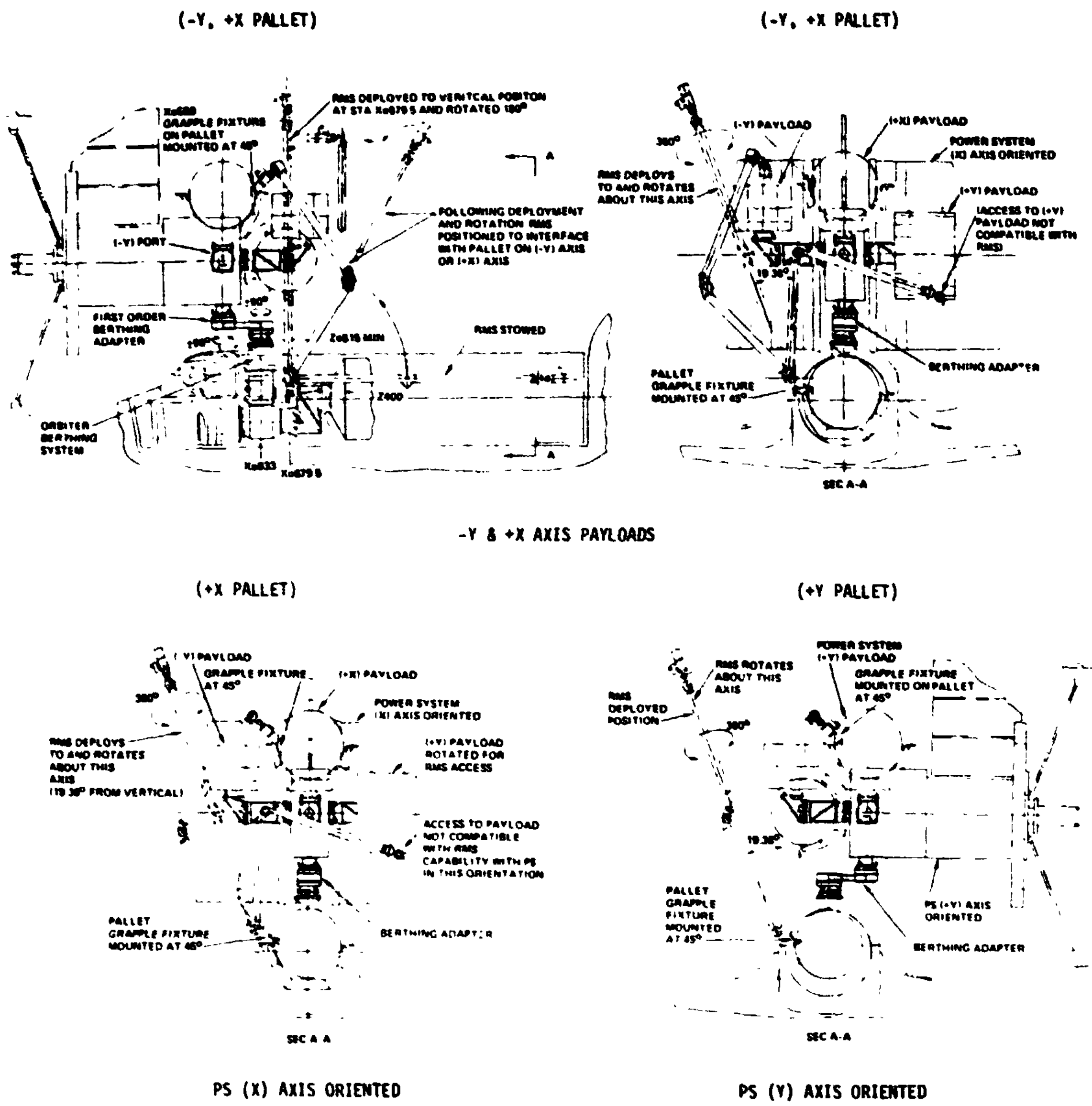


Figure 6.1.3-2 First Order Platform Orbital Operation/Pallet Access

OPTIONS	COMMENTS
POWER SYSTEM/ORBITER DUAL HUB BERTHING ADAPTER • Provides Interface at Sta $X_0 = 550$ and $+ Z_0 = 515$ (MSFC Baseline) • Provides Active Capture Latching and Umbilical Engagement at Power System Interface • Provides ±90° Rotational Capability for Maximum RMS Utilization • Interfaces with Orbiter Berthing System	• Provides Clearance for RMS Manipulation to Access Payloads • Places All Payloads Within RMS Reach Envelope, Including Power System Reboost Module • Interfaces With Common Orbiter Berthing System • Avoids Impact on RMS • Rotates Platform to Minimize Cargo Bay Obstruction
RMS MODIFICATION • Provide RMS Upper Arm Roll Capability • Provide Second RMS	• Would Eliminate Need to Berth at Sta X_0 550 • Would Eliminate (1) Rotating Hub in Above Berthing Adapter • Would Still Require ±90° Rotation at Orbiter/Power System Interface to Access +Y Payload • Requires Costly Modification to RMS • Eliminates Rotary Joints • Requires 2.1M Standoff to Provide Interface at X_0 550 • Payload Cost and Weight Penalty
INTEGRATED BERTHING/ LOADING CAPABILITY IN POWER SYSTEM	• Reduces Launch Weight Penalty to Power System Launch Only • May Have Excessive Cost and Weight Penalty on Power System • Reduces Flexibility of Common Design for Un-pressurized/ Pressurized Interface • Single Adapter Versus Multiple Adapters If Additional Power System are Required

Table 6.1.3-2 First Order Platform Pallet Access

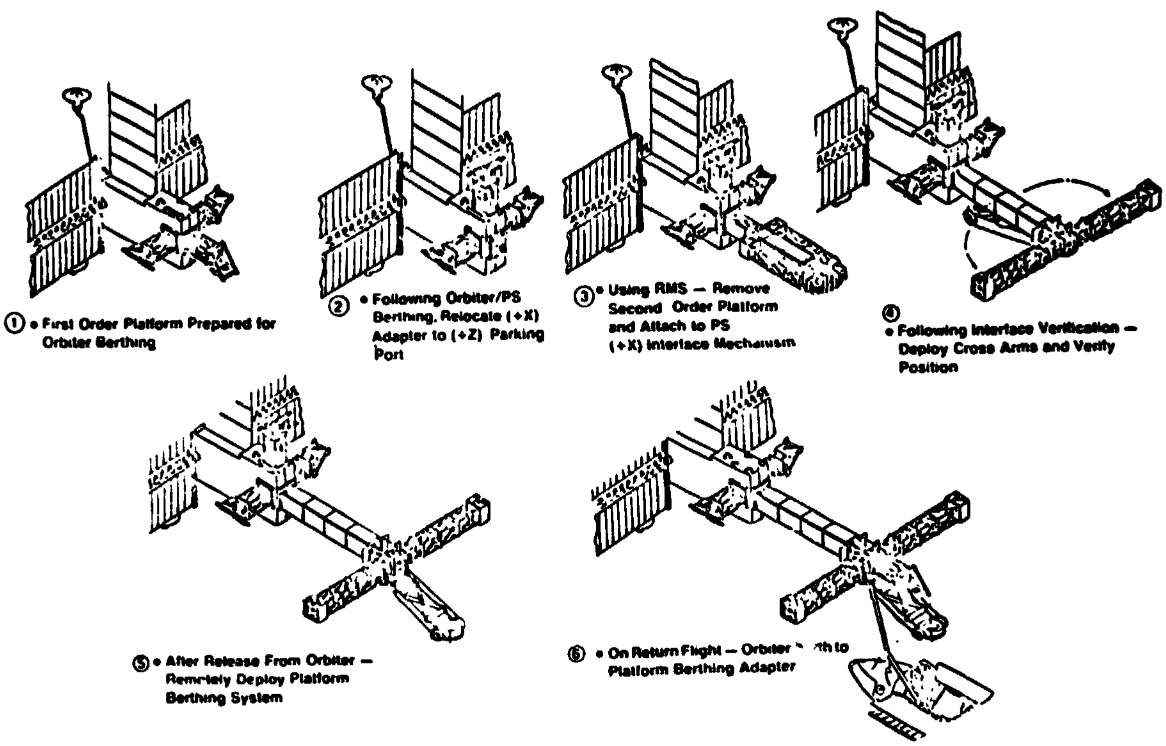


Figure 6.1.4-1 First-Second Order Transition

During this phase of the activation, the 2nd order berthing mechanism remains stowed. Upon completion of the verification, the Platform is released from the Orbiter. With the Orbiter still in the vicinity, the Second Order Platform Berthing System is remotely deployed and verified. The Orbiter then prepares for the return to earth. During the interim period, before the next launch, it may be necessary to deactivate and stow the payload placed on the PS (+Z) port. Table 6.1.4-1 lists the pallet access options for this configuration.

On a subsequent flight, the RMS captures the SASP and performs berthing operations to join the SASP Orbiter at the 2nd Order Berthing System interface. Prior to unloading the cargo bay, the berthing system rotates the Orbiter into position for the RMS to remove the payload stowed on the PS parking port and repositions it to the platform (+X) port. After, subsystem verification payloads are removed from the cargo bay and placed on the Platform.

OPTIONS	COMMENTS
• SASP/ORBITER, DUAL HUB, TELESCOPING BERTHING ADAPTER	
• PROVIDES INTERFACE WITH ORBITER BERTHING SYSTEM (MSFC BASELINE SYSTEM)	• BERTHING ADAPTER CAN BE INTEGRAL WITH PLATFORM • NO ORBITER MODIFICATIONS REQUIRED
• ENABLES RMS TO SERVICE ALL PORTS FROM A SINGLE BERTH POSITION	• COST AND WEIGHT PENALTY ON SASP • COMPLEX DEPLOYMENT AND CONTROL SYSTEM
• PROVIDES ROTATIONAL CAPABILITY TO SERVICE PS	• ENABLES ORBITER SYSTEM TO SERVICE ALL PS AND SASP SUBSYSTEMS AND PAYLOAD INSTALLATIONS
• AFT MOUNTED RMS	• ENABLES SINGLE DESIGN BERTHING SYSTEM FOR BOTH 1ST AND 2ND ORDER PLATFORM
• PROVIDES ACCESS TO ALL CROSS-ARM PORTS FROM SINGLE BERTH	• COST AND WEIGHT PENALTY ON PAYLOADS • REQUIRES MODIFICATION TO ORBITER
• UTILIZES 1ST ORDER BERTHING SYSTEM	• MAY EXCEED CAPABILITY OF RMS TO RELOCATE CLUSTER FOR PS ACCESS
• CLUSTER RELOCATED TO ACCESS PS	• REQUIRED 1ST ORDER ADAPTER TO PROVIDE ROTATIONAL CAPABILITIES
• MULTIPLE BERTHING OPERATIONS	• PLACES PAYLOADS WITHIN REACH OF SINGLE RMS • EXCEEDS CAPABILITY OF ORBITER RENDEZVOUS SYSTEM • EXCEEDS CAPABILITY OF RMS TO MOVE ORBITER FROM PORT TO PORT

Table 6.1.4-1 Second Order Platform Pallet Access

6.1.5 Extended Second Order Payload Loading

On subsequent flights the Second Order SASP is extended to accommodate a greater number of payloads and larger payloads as shown in Figure 6.1.5-1. The increased size of the SASP places payloads outside the capability of the RMS. The Second Order Berthing System, discussed in Sections 4 and 5 of this report, is used to place the Orbiter at discrete positions within the RMS reach envelope. Initial berthing is accomplished along the (X) axis using the RMS. From this position the RMS can reach the inner (-Y) port. The RMS can also reach the (+Y) port providing the payload is a single pallet design. A large payload shown requires the adapter to rotate the Orbiter closer to the payload CG. The outer ports are accessed by rotating and telescoping as necessary to place the Orbiter within range for the RMS. It is also necessary that the cross arms be rotated 90°, as shown to reduce the RMS reach requirements. Payloads on the Power System are accessed by

rotating the berthing system forward along the (X) axis until the RMS is within range of the payload. The payloads are to be rotated 90° aft to reduce the berthing system/Orbiter displacement. The 2nd order berthing adapter places all payloads and PS subsystems within working range of the RMS with a single Orbiter berthing operation.

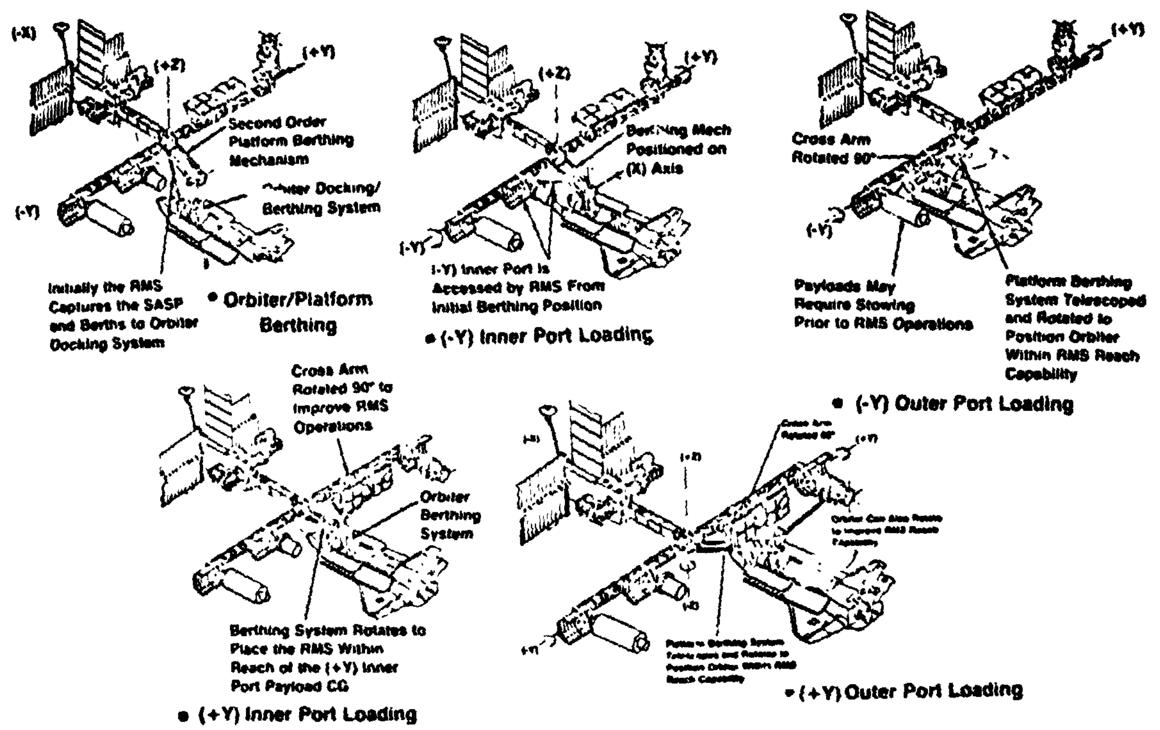


Figure 6.1.5-1 Extended Second Order Payload Loading

6.1.6 Alternate Second Order Platform Loading

The physical characteristics of the basic, and/or extended Second Order Platform places the payload outside the capability of a single RMS without additional special equipment. An alternate method of accessing large payloads on the Second Order Platform is the installation of a second aft mounted, RMS to be used in conjunction with the First Order Berthing System defined in Sections 4 and 5.

The aft mounted RMS would attach to the starboard longeron at approximately Sta Xo 1220. The rotational capabilities of the First Order Berthing System places the inner payloads within the range of the forward RMS and the outer payloads within range of the aft RMS. Access to the payloads berthed to the Power System requires the SASP be repositioned on the Orbiter. The forward RMS will be required to remove the SASP from the berthing adapter and translate the entire cluster aft until the Power System interfaces with the Orbiter berthing system. Rotation of the berthing adapter places the (Y) axis payloads within range of the forward mounted RMS.

Additional study will be necessary to fully investigate the feasibility of this alternate approach, in terms of RMS capabilities, Orbiter modifications, cost, operational reach envelope and procedures, cluster control characteristics, etc.

6.1.7 Other Operational Concepts Developed Early in Study

The remainder of this on-orbit operations section presents a number of concepts developed prior to the one selected and described prior to the one selected and described in 6.1.3, 6.1.4, 6.1.5, and 6.1.6 just previously. These other concepts include:

- All deployable arm configuration.
- RMS plus double-elbow berthing mechanism.
- RMS plus multiple Orbiter berthing.
- Cross-arm - all deployable.
- Trail arm all deployable.
- Recommended platform - docking tower only with multiple placement.

6.1.7.1 All Deployable Arm Configuration

The on-orbit assembly sequence is shown in Figure 6.1.7.1-1. Following launch operations, the Orbiter berthing adapter and RMS are deployed and verified. The RMS removes the stowed SASP and prepares for berthing of the Power System. After rendezvous, the RMS captures the PS and berths to the SASP. The interfaces are verified and the PS extension is deployed. Initially, the cross-arm sections are rotated and locked; however, they are not deployed. The center (trailing) arm is deployed and the Materials Experiment Carrier (MEC) is removed from the cargo bay and positioned on the arm.

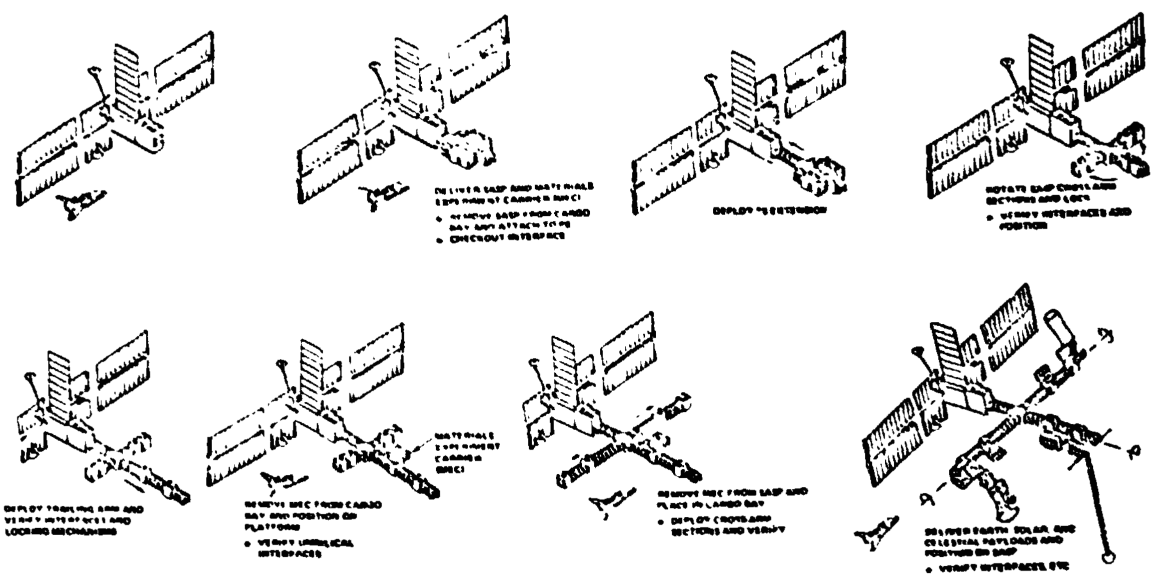


Figure 6.1.7.1-1 Reference Configuration On-Orbit Assembly Sequence

On subsequent flights, the Orbiter berthing adapter is deployed and prepared for reberth operations. After reberthing operations, the cross-arm sections of the Platform are deployed to receive solar and/or celestial viewing payloads. The MEC is removed and returned to earth. Additional flights deliver earth, celestial, and solar viewing payloads to maximum capability of the SASP.

6.1.7.2 RMS Plus Double-Elbow Berthing Mechanism

Shown in Figure 6.1.7.2-1 is a candidate berthing/assembly concept using the Orbiter RMS and a double-elbow/double rotation berthing arm. The berthing arm places the SASP overboard and clear of the cargo bay, providing full RMS access to payloads. Initially, the Orbiter berthing arm and SASP systems are launched, deployed, berthed, and prepared for berthing with the 25 kW Power System. Following rendezvous the PS is captured by the RMS and berthed to the SASP. After checkout, the PS solar arrays are deployed and the platform arms are rotated, deployed, and oriented for payload berthing. The SASP rotary joints orient the berthing interfaces to add flexibility to the RMS. The entire PS/platform assembly can be rotated to the opposite side of the Orbiter to provide RMS access to all elements of the Platform.

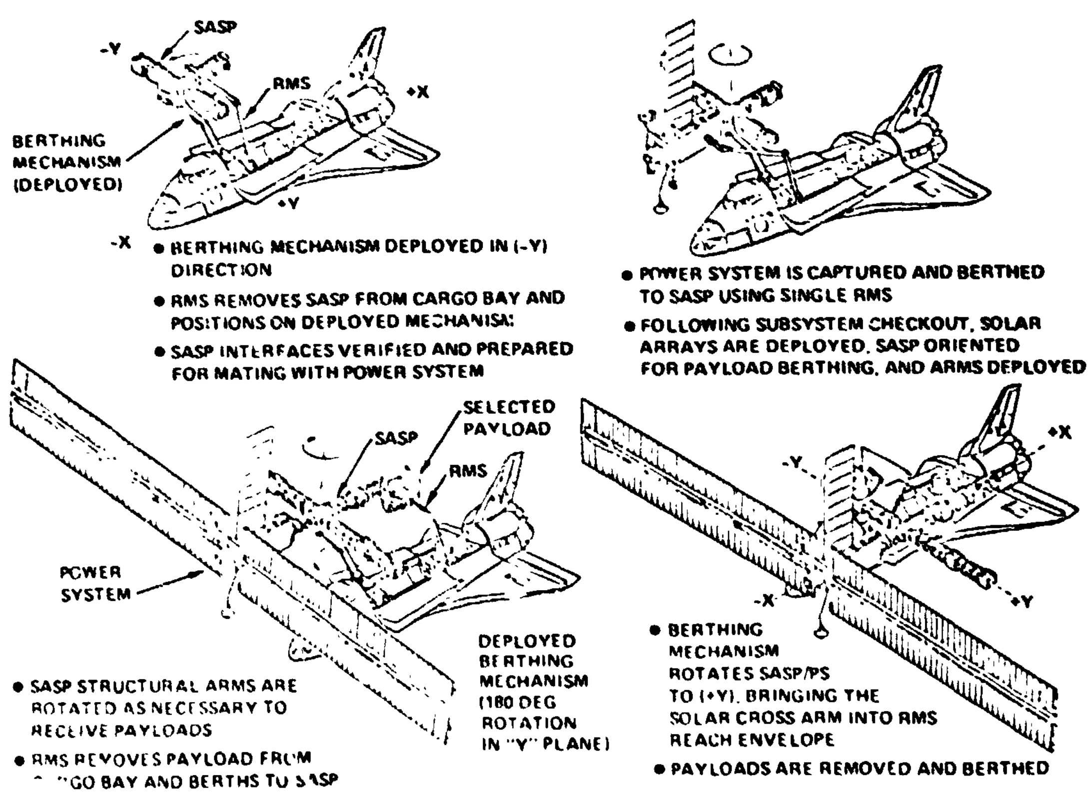


Figure 6.1.7.2-1 SASP On-Orbit Operations (RMS with Double-Elbow Rotating Berthing Mechanism)

6.1.7.3 RMS Plus Multiple Orbiter Berthing

Shown in Figure 6.1.7.3-1 is a candidate berthing/assembly concept using the Orbiter RMS and the Power System berthing adapter. Initially, the Orbiter/PS berthing adapter is deployed and the stowed SASP is positioned on the adapter. After checkout and verification, the SASP is berthed to the PS using the RMS. After checkout of vital systems through the berthing adapter interface, the solar arrays are deployed and the platform arms are rotated into position and deployed. Prior to removal of payloads from the cargo bay, the RMS repositions the PS/SASP to an appropriate berthing port to permit access to the cargo bay and also to permit the RMS to position the payload pallets.

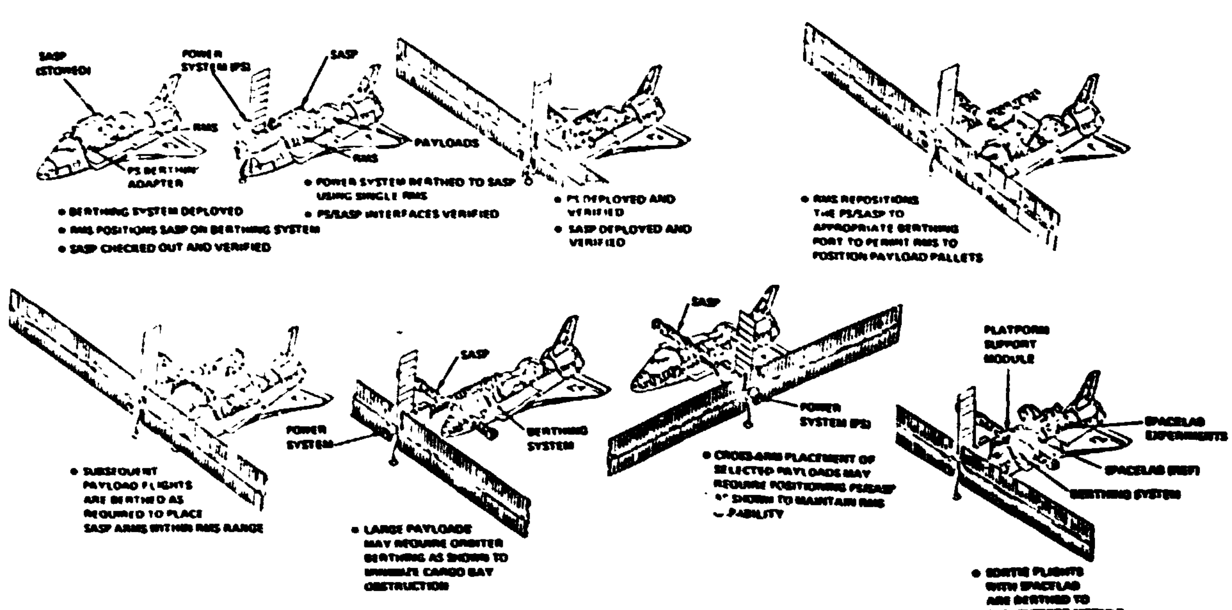


Figure 6.1.7.3-1 SASP On-Orbit Operations
(RMS with Multiple Orbiter Berthing Provisions)

Subsequent flights are berthed as required to place the Platform within the RMS reach envelope. Large payloads may require the Orbiter to be positioned with the entire assembly forward to minimize cargo bay obstruction and RMS interference. Cross-arm placement of solar or celestial payloads

may require the SASP/PS to be positioned 90° to the Orbiter center line to maintain RMS capability.

Sortie flights with Spacelab can be berthed to the Platform's support module since minimum RMS operation is required. The sortie mode permits crewmen to exit Orbiter and take samples from SASP payloads into the Spacelab for analysis.

Lack of rotational capability of the MSFC baseline PS berthing adapter restricts the SASP configurations to avoid interference with Orbiter tail section, cargo bay payloads and/or RMS reach envelope.

6.1.7.4 On-Orbit Assembly Sequence - Cross Arm Concept

As shown in Figure 6.1.7.4-1, initially, the Orbiter berthing adapter and RMS are deployed and verified. Following adapter deployment, the RMS positions the Platform in preparation for berthing to the Power System. Following rendezvous, the RMS captures the PS and performs berthing operations. After verification of PS/SASP interfaces, the structural arms are deployed and verified. Solar and/or celestial viewing payloads are removed from the cargo bay and positioned on the cross-arm as appropriate for viewing requirements. After verification of all latching interfaces the Platform is released to orbit.

On subsequent flights, the adapter is deployed and prepared for reberthing operations of the Platform's system. Following rendezvous, the RMS captures the Platform and performs berthing operations to join SASP with the Orbiter. After verification, payloads are removed from cargo bay and placed on Platform. Following verification, the Platform is released to orbit.

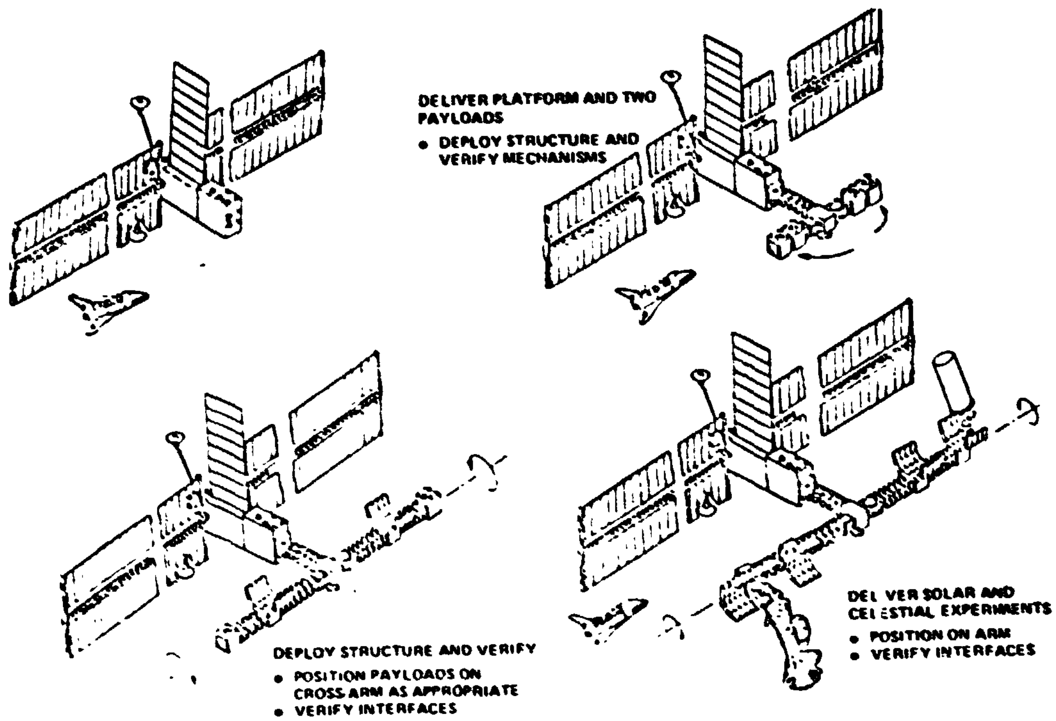


Figure 6.1.7.4-1 On-Orbit Assembly Sequence
Cross-Arm Concept

6.1.7.5 On-Orbit Assembly Sequence - Trail-Arm Concept

Following launch operations, the Orbiter berthing adapter and RMS are deployed and verified. The RMS positions the Platform on the adapter in preparation for berthing with the orbiting Power System. After completion of the rendezvous phase, the RMS captures the PS and performs berthing operations. After verification of interfaces, the Platform is deployed and verified.

The RMS removes the Materials Experiment Carrier (MEC) from the cargo bay and positions on Platform. After verification of interfaces, the Platform is released to orbit.

Subsequent flights deliver earth, anti-earth and magnetic field experiments for installation on the platform trailing arm. Five such payloads can be accommodated on the Platform. The sequence is shown in Figure 6.1.7.5-1.

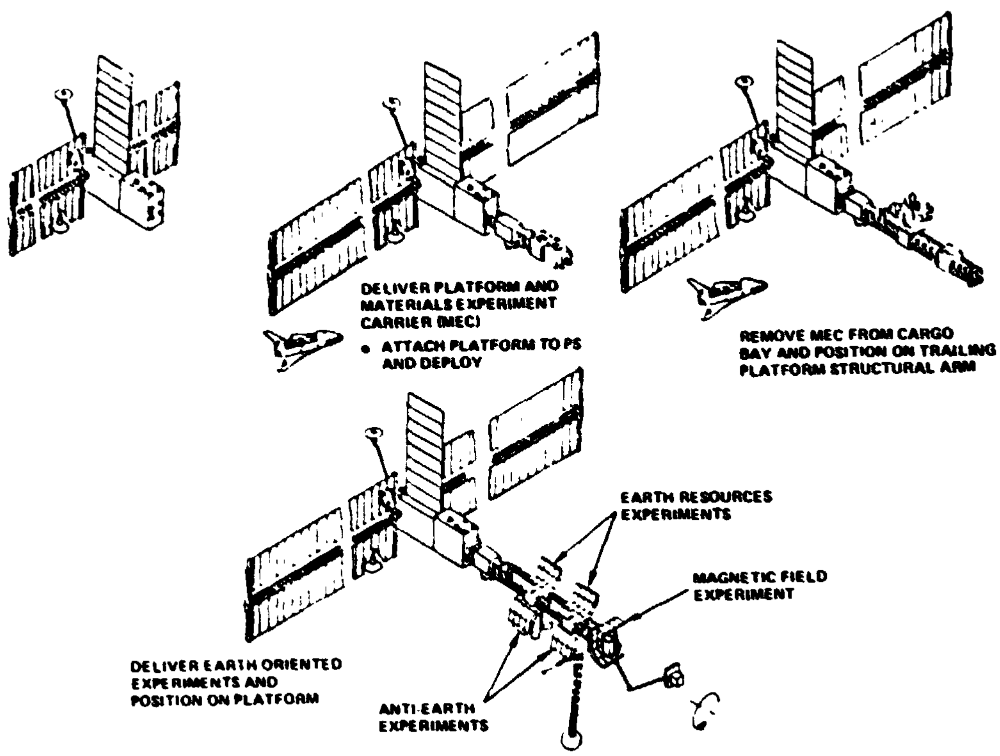


Figure 6.1.7.5-1 On-Orbit Assembly Sequence
Trail Arm Concept

6.1.7.6 Second Order Platform Activation - Docking Tower Only

The platform activation sequence shown in Figure 6.1.7.6-1 assumes that the 25 kW Power System has been placed on-orbit by a previous Orbiter flight. Initially, the Orbiter berthing system is deployed and verified. Following rendezvous, the Power System is berthed to the Orbiter using the RMS. After verification of the Power System and the PS/Orbiter interfaces, the SASP is removed from the cargo bay and berthed to the Power System along the (X) axis. With the RMS still attached to the SASP, the PS/SASP interfaces are verified. Following verification, the RMS is stowed and the structural arms are rotated into position and the telefold sections are deployed. Each of the SASP subsystems, the latching mechanisms, and the berthing mechanisms are verified and the Platform released from the Orbiter and placed on-orbit.

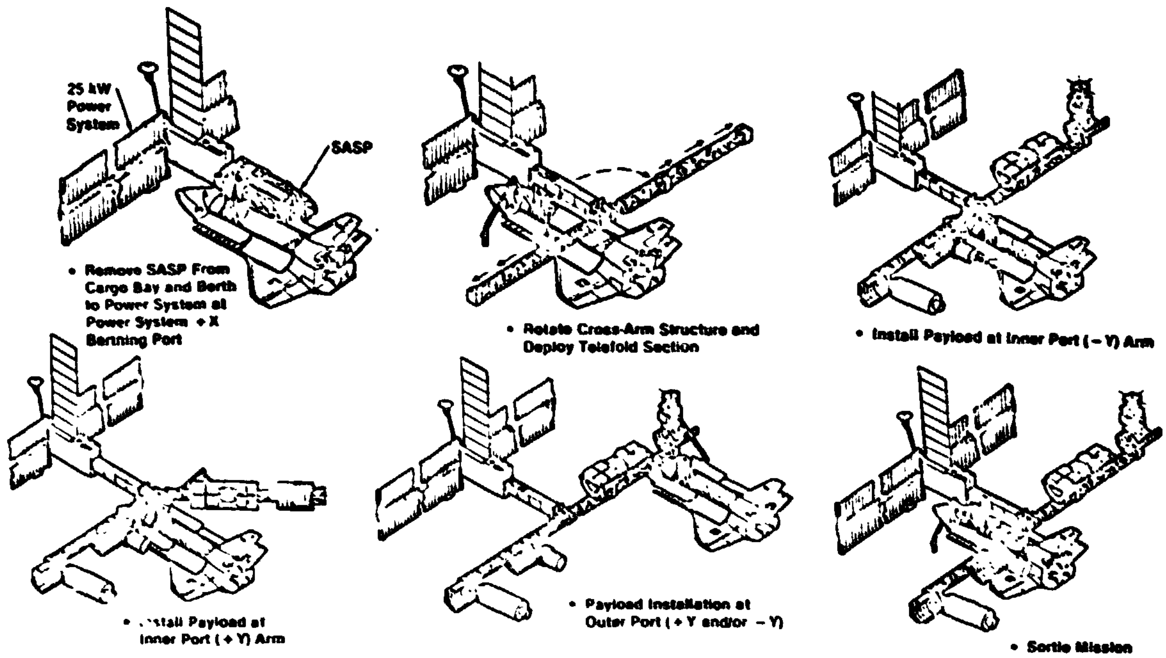


Figure 6.1.7.6-1 Science and Applications Space Platform, Second-Order Platform Activation (Cross-Arm Configuration)

The initial flight is dedicated to delivery of the Platform only. The size of the stowed SASP required the maximum length available in the cargo bay, preventing delivery of any payloads or the initial launch.

On subsequent flights, the Orbiter berthing adapter is deployed and prepared for reberthing of the PS/SASP. Following rendezvous, the RMS captures the PS/SASP and performs berthing operations to join the PS/SASP with the Orbiter at the SASP support module berthing port. This berthing location is temporary only to load and unload cargo. From this berthing position, the Orbiter RMS can reach the inner berthing ports on the +Y and -Y arms. To place a pallet on the inner port, the arm is rotated 90° about the "Y" axis and verified. Payloads are then removed from the cargo bay and placed on the Platform. When placing or removing a payload on the inner port on the (-Y) arm, the port must be brought within reach of the 15m long RMS. The arm is

first turned 90° about the -Y axis and then rotated 45° to bring the berthing port closer to the cargo bay. After verification of the position, ꞓ .oads are removed from the cargo bay and placed on the Platform. Following verification, the arm is returned to its flight position. The Orbiter is then relocated to the PS/Orbiter berthing port for the remainder of the Orbiter's staytime.

Positioning payloads on the outer ports of the cross arm requires the Orbiter be berthed at those locations. This is due to the spacing requirements between experiments. These requirements exceed the reach capability of the RMS.

After deployment of the Orbiter berthing mechanism, the RMS captures the SASP and performs berthing operations to join the SASP with the Orbiter at the outer berthing port. This location is temporary, only used to load or unload cargo. After verification of the interface, the RMS removes the payload from the cargo bay and places it on the Platform. After payload verification, the Orbiter is reberthed to other platform ports to allow placement of additional payloads, or reberthed to the Power System for the remainder of the Orbiter staytime.

Sortie flights with Spacelab can be berthed to the PS/SASP, since minimum RMS operation is required. The sortie mode permits crewmen to exit the Orbiter and take samples from SASP payloads back into the Spacelab for analysis.

6.1.8 First Order Platform Activation Timelines

A credible low cost platform option consists of early payload deployment directly with the Power System. The viewing and configuration driver analysis work reported in Task 2 (Section 3.0) established the need for (1) payload

pallet standoff from the Power System to preclude pallet/payload collision interference, and (2) pallet pointing freedom provided by the three position arm gimbal (0 $\pm$ 90°) and hinge. Freedom of payload movement is necessary to assure reasonable payload viewing opportunities.

Figure 6.1.8-1 provides a preliminary timeline estimate for initial launch of the PS, the Reboost Module, and the Payload Berthing Structure arms. Current estimates indicate this would constitute the first launch element. Based on the Flight Scenario I - First Order Platform (57°, 400 km orbit), contained in Reference 6.A-1, the activation sequence is continued as shown in Figure 6.1.8-2. Review of the scheduled launch suggests that it should be enlarged to include also payloads SPP-1 and SPP-2, Space Plasma Physics, Pallets 1 and 2. The only effect of increasing the number of payloads launched would be a more cost effective payload scenario. Two items are worthy of note. At the time of PS capture by the RMS the PS altitude control system (CMG's) must be disabled to preclude unacceptable RMS difficulties. (A similar but reverse situation will exist at Orbiter departure; the PS altitude control system must be reactivated.) The second item of interest that will require further study is the need to delay experiment operation until the contamination level decreases to an acceptable level after Orbiter departure. This concern about contamination is shown again in Figure 6.1.8-3.

Preberthing activities include shutdown and covering of sensitive equipment prior to Orbiter berthing. Not all payloads will require this preventive measure; however, approximately half of the payloads have expressed contamination concern.

The requirements for servicing and maintaining payloads will require further study as payload definition is improved and payload service requirements can be translated into the need for RMS and EVA operations.

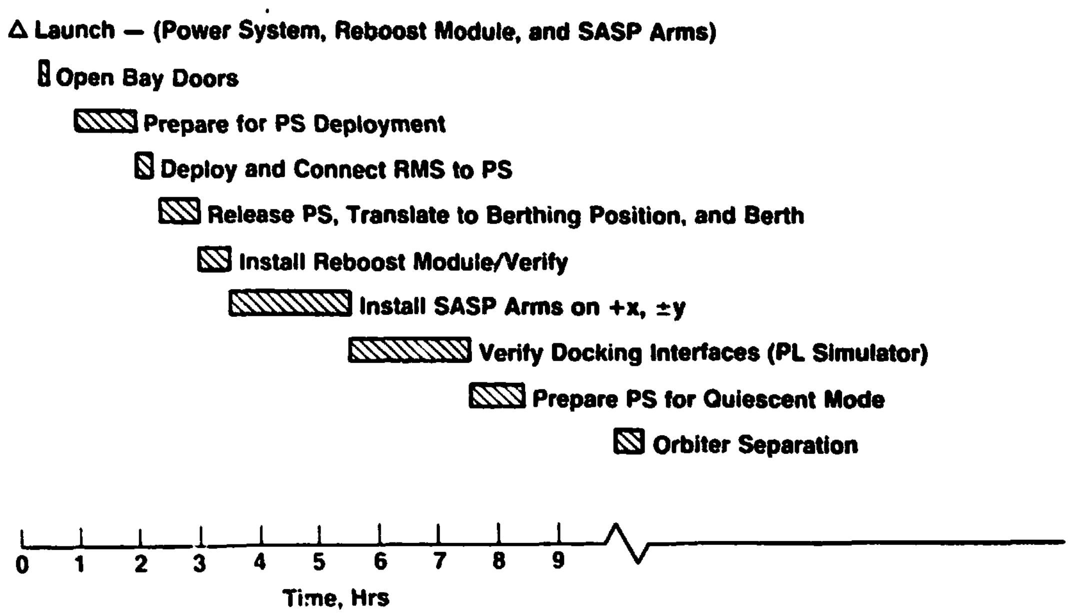


Figure 6.1.8-1 First Order Platform Activation

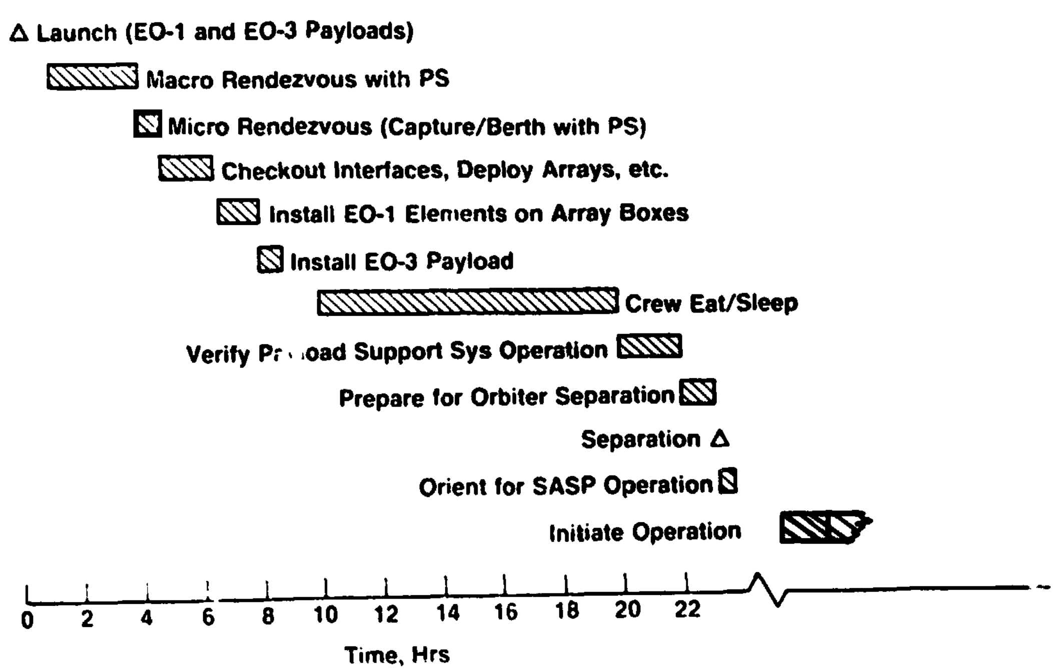


Figure 6.1.8-2 First Order Platform Activation (Continued)

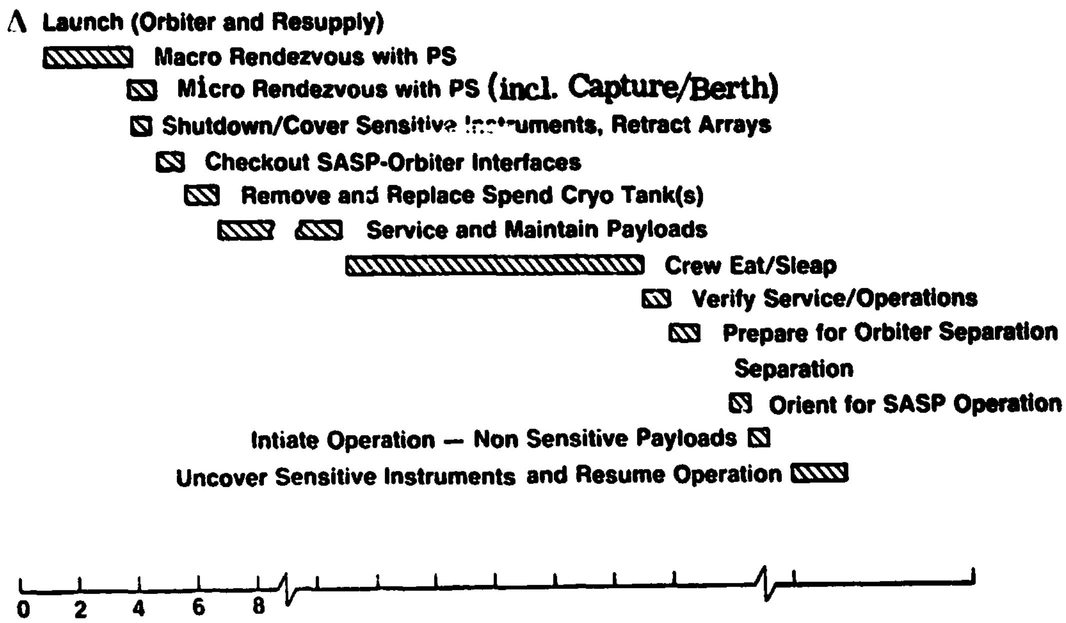


Figure 6.1.8-3 Servicing Visit for Astronomy Payloads

6.2 GROUND OPERATIONS

6.2.1 Overview

The capabilities planned for pre-launch operations related to SASP include the following:

- Checkout and processing of single and multiple payloads.
- Checkout and processing of the Platform.
- Vertical and horizontal processing of the Platform/payload combinations
- Special processing arrangements for high-inclination orbit launches out of Vandenberg AFB.

A key trade involved in planning KSC operations centers on the need for dedicated of multiple Payload Processing Facilities. A key issue for the Platform System is the advantage of closed-loop checkout and factory vs launch site checkout.

A special services for payload in ground operations will be the central provisioning of payload carriers (pallets). Emerging concepts in this area include:

- A dedicated KSC facility for processing all platforms, pallets, and payloads.
- A TDY KSC team for processing platforms and payload integration at Vandenberg AFB.

KSC

Figure 6.2.1-1 illustrates the alternate processing paths at KSC for normal vs hazardous payloads.

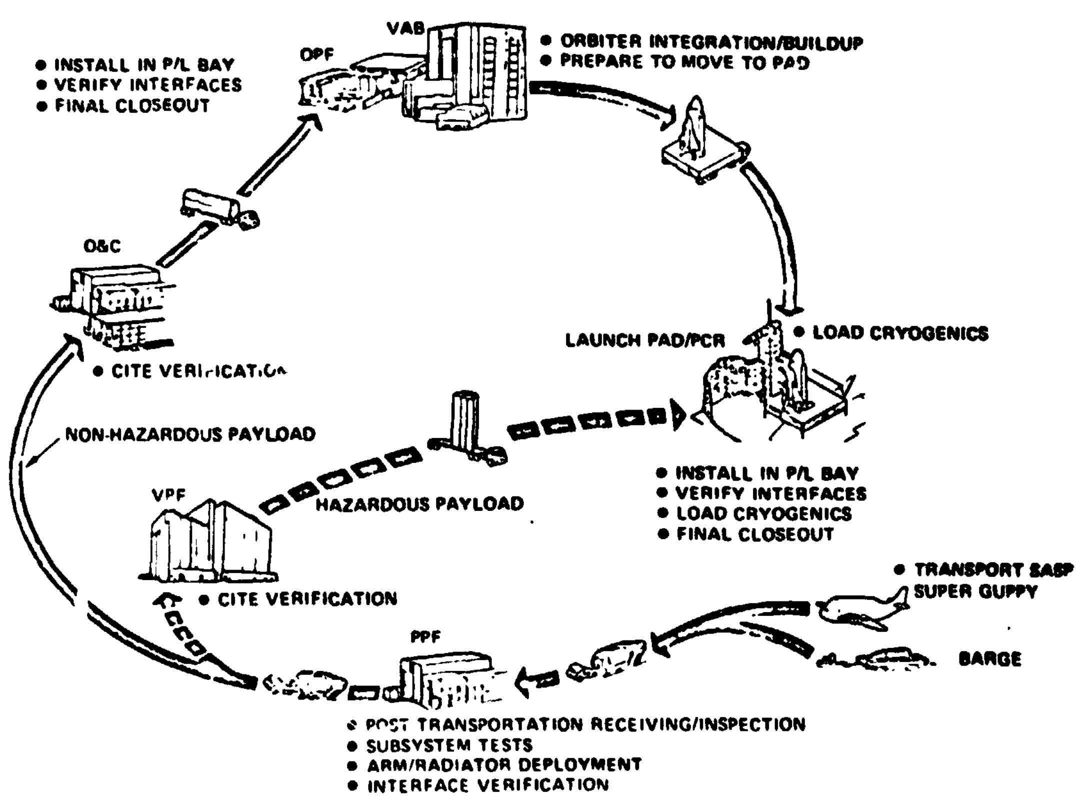


Figure 6.2.1-1 SASP KSC Ground Test Flow Options

6.2.2 Factory vs Launch Site Checkout

At the present time, it is our concept that is meant in a one-step-two-step checkout sequence for successive platforms. In this concept the first article produced would be checked out at the factory. Next the Platform, and the GSE would be shipped to KSC for pre-launch checkout. Later platforms would be checked out only at KSC with the one set of GSE resident there.

An all-factory checkout approach would increase total flow time, increase cost for double checkout and require that the one set of GSE planned be shipped back and forth from factory to KSC.

The "KSC checkout after first platform checkout" approach, with adequate spares support would present no additional risk over the factory/KSC checkout switchback approach, and the former would be less expensive.

6.2.3 Closed Loop Checkout

This area involves a major decision requirement (not addressed within the scope of this study) as to whether end-to-end system testing is required, being together the Payload Operations Control Center, the TRSS power system and platform simulators and the payload.

Figure 6.2.3-1 illustrates some of the basic interface and checkout relationships in prospect in this area.

6.2.4 Element Flows

Figure 6.2.4-1 illustrates the payload/carrier/platform flows including single PI type payloads as well as multiple PI/payload assemblages.

6.2.5 Activity Timelines

Figures 6.2.5-1 through 6.2.5-4 present timelines of the Platform for viewing

payloads and the manned access module for crew-tended or operated Life Science or Materials Processing payload laboratories.

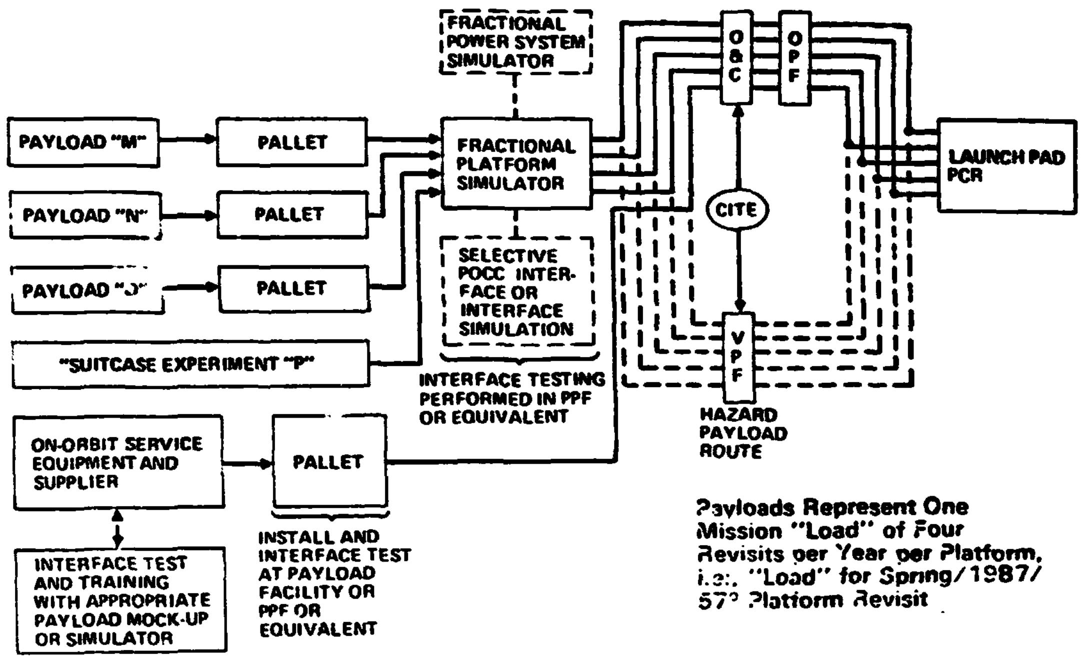


Figure 6.2.3-1 Payload/Platform Interface Verification KSC Ground Operations

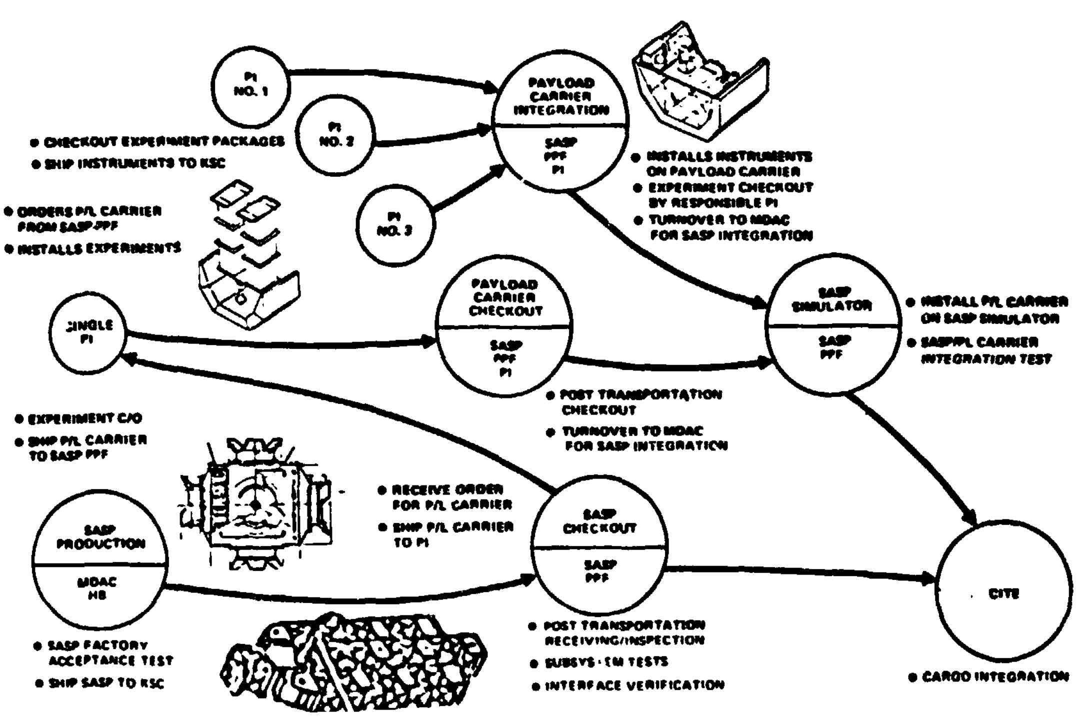


Figure 6.2.4-1 Payload/Carrier/Platform Flows

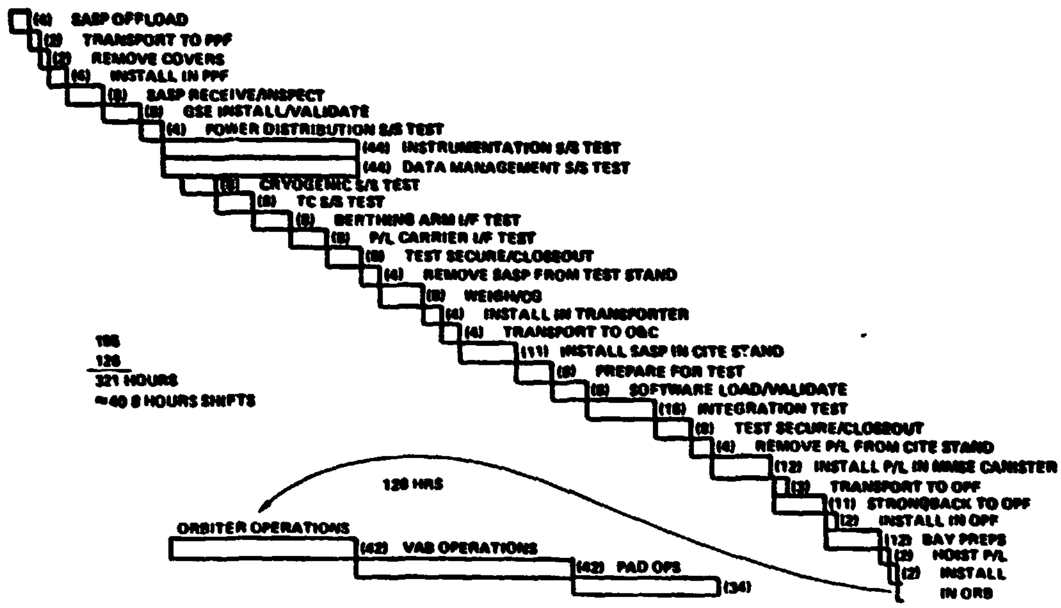


Figure 6.2.5-1 SASP Launch Site Operations
Viewing Platform - Horizontal Flow

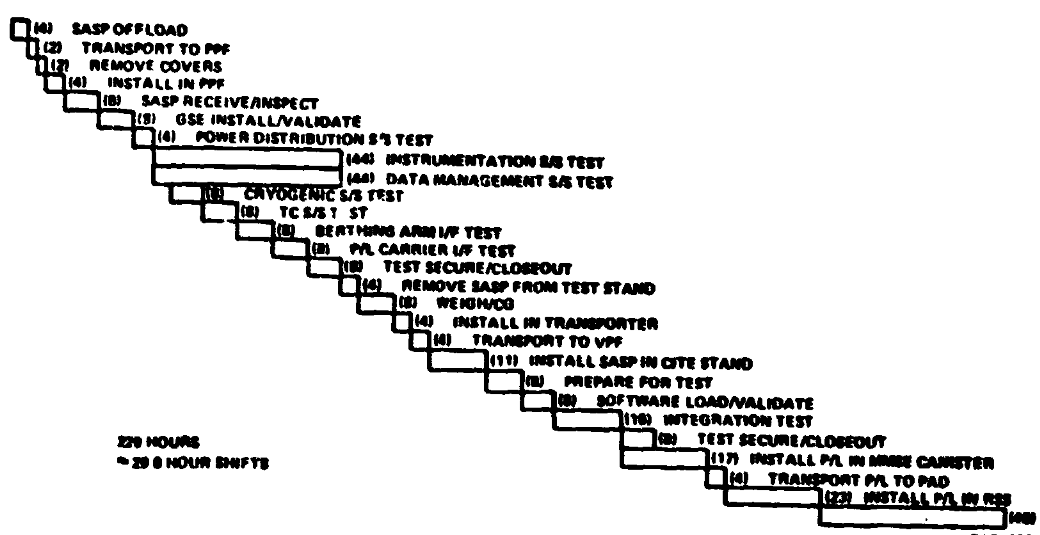


Figure 6.2.5-2 SASP Launch Site Operations
Viewing Platform - Vertical Flow

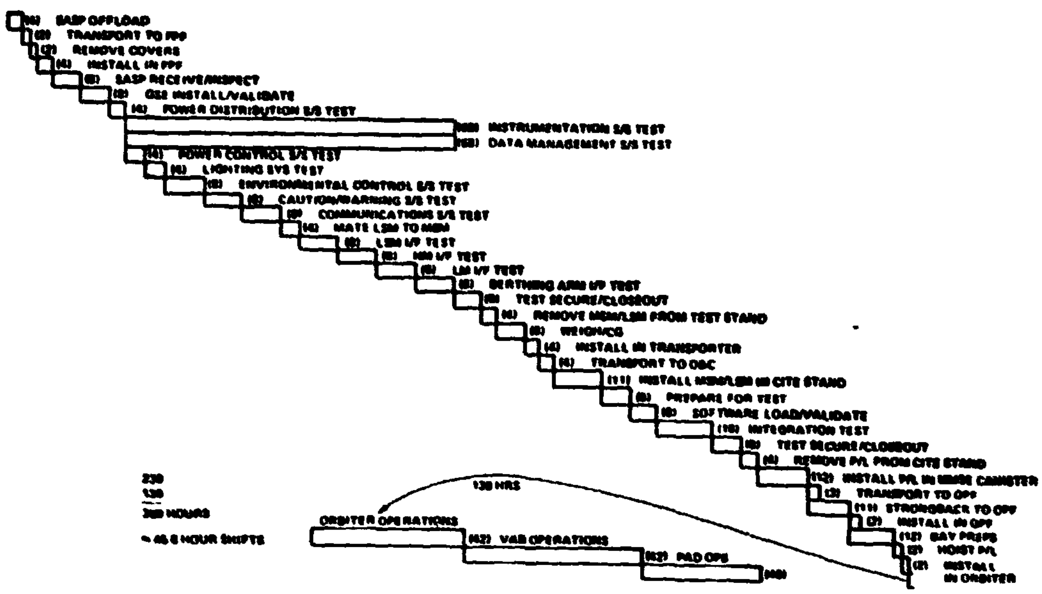


Figure 6.2.5-3 SASP Launch Site Operations
Manned Support Module - Horizontal Flow

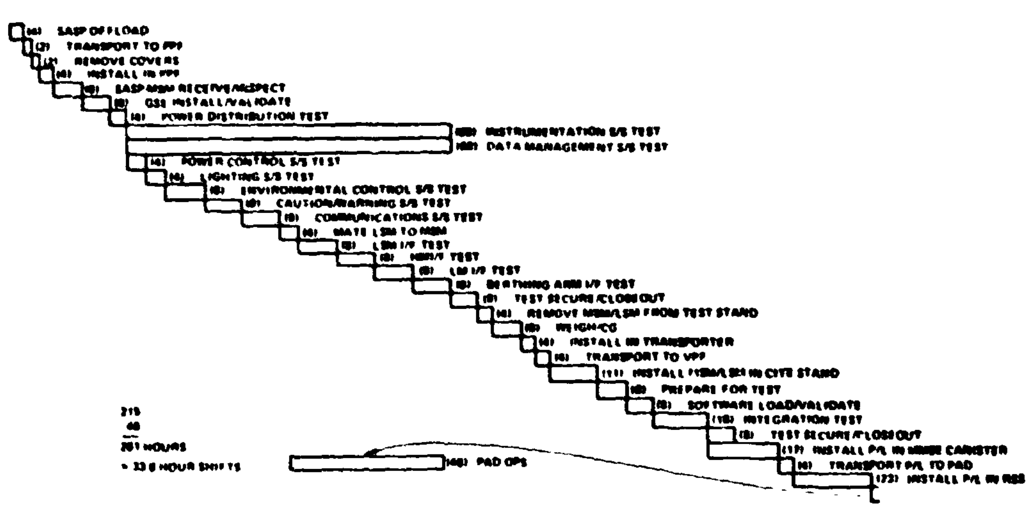


Figure 6.2.5-4 SASP Launch Site Operations
Manned Support Module - Vertical Flow

6.2.6 Dedicated vs Multiple Payload Processing Facilities

A listing of the features of each approach is given below. Our current concept favors the dedicated facility approach.

Dedicated	Multiple
• Central area for C/O of all SASP's and payloads	• Parallel processing of payloads
• GSE permanently located	• Autonomous control by PI
• Stable environment for C/O crew	• Only pay for actual time facility is used
• Ground Maintenance and service center continguous	• GSE must be shipped to multiple locations
• Parallel processing of payloads	• Risk damage to GSE because of additional handling
• Number of payload processed per year makes this approach economically feasible	

6.2.7 KSC vs VAFB Checkout for VAFB Launches

A listing of the feature of each approach is given below. VAFB checkout is currently favored using a KSC TDY team.

KSC	VAFB
• Centralized C/O areas for all SASP's and payloads	• Less transportation handling of flight hardware
• Increased risk of flight hardware damage due to handling	• Prelaunch C/O performed at launch site
• Increased risk of faulty component on orbit	• Increased risk of GSE hardware damage due to handling

Figure 6.2.7-1 illustrates the Platform/Payload flow of operations at VAFB.

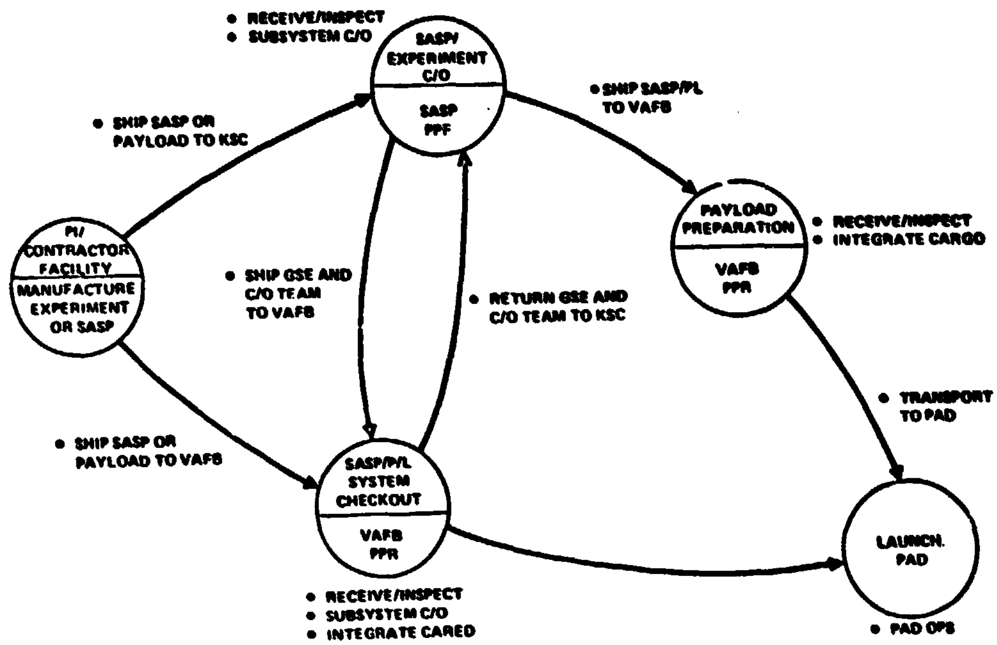


Figure 6.2.7-1 SASP/Payload Flow at VAFB

6.3 LOGISTICS AND MAINTENANCE

6.3.1 Total Requirements for Logistics and Maintenance

MDAC's approach to SASP Logistics and Maintenance is to integrate requirements for all systems in the orbital assembly and provide a single capability for support. Taking an integrated approach to Logistic and Maintenance will provide cost benefits by eliminating redundant effort. Delineating the Logistics and Maintenance requirements for each system will provide visibility for operational phase planning so that early analyses and designs can be focused on minimizing operations and support costs and resource requirements. Figure 6.3.1-1 defines the envelope of requirements and major impacts in prospect in this area.

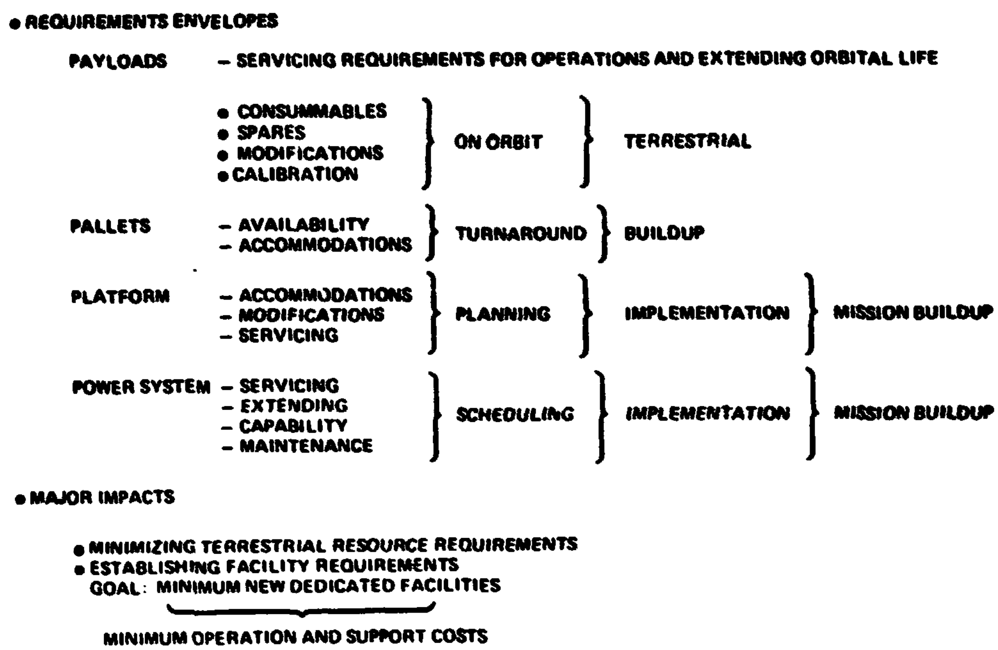


Figure 6.3.1-1 Total Requirements for Logistics and Maintenance

6.3.2 Emerging Concepts

Three levels of support are anticipated, namely, orbital, terrestrial launch site, and terrestrial (offsite). Logistics and Maintenance design support for experimenters is also planned. Scheduled servicing and maintenance will be driven by a priori payload requirements, for example: tape and laser dye change, replenish cryogens, modifications, and calibration.

Dynamically scheduled service and maintenance will also be driven by a posteriori payload/platform/PS requirements, such as battery removal and replacement. Preflight tasks for Logistics and Maintenance will include:

- Determination of mission tasks - scheduled and unscheduled
- Assessment of criticality to determine visitation requirements/opportunities

- Assembly of resources and load logistics/maintenance module
- Training of crew for specific logistics/maintenance mission tasks
- Placement of logistics/maintenance module in Orbiter and load cryogens if required

6.3.3 Power/SASP Interfaces

The Power System L&M requirements are complementary with the SASP L&M requirements. MDAC recommends integrating these requirements to eliminate duplication of effort to save L&M costs.

Interfaces between the two systems include:

- Piggy-back Power System/Platform L&M tasks, facilities, resources.
- Power System/Platform/Payload L&M missions complementary in resources and crew tasks.
- Task integration very cost effective.
- Integrated planning will be efficient for integrated logistics, training,and maintenance programs.

6.3.4 Redundant Design Versus Orbital Maintenance

This trade could result in major cost savings. The selection criteria includes total cost, cost to whom, safety, operational life expectancy, criticality of recoverability from malfunction, potential commonality of tools and trailing with other maintainable system or shuttle elements, exploitation of periodic shuttle visits, and impact on item design for optimal performance.

6.3.5 Capabilities for Service and Maintenance

The overall Service and Maintenance capabilities include Terrestrial and orbital resources, techniques and planning. The major task in defining

such capabilities will be to emp oy as much STS present and planned capability as possible to avoid excessive additional operational costs.

The terrestrial capabilities include orbital hardware acquisition, scheduling resource deliveries for launch, integration locations, and experimenter support during design. The orbital capabilities include crew capabilities, Shuttle capabilities such as RMS, MMV, and tools, plus overall visitation opportunities.

6.3.6 Design Assistance

Design assistance will be provided by the platform contractor to experimenters to assure that experiments can be serviced and maintained in orbit safely and economically.

The options in such a service include a design manual, design consultants, both or none of the above. The selection criteria for such decisions include costs, safety, and serendipitous benefits. The impacts in the above options are as follows:

- Cookbook should be inexpensive and helpful in fifty percent of the cases.
- Consultants should be helpful in most cases, could be expensive requires special kind of individual.
- Combined approach should solve all problems and reduce requirements for many consultants.
- STS payload accommodations handbook might be sufficient.

6.3.7 Accommodation in Minimum Terrestrial Facilities

In long duration programs such as the Platform, terrestrial facilities for logistics and maintenance can be a cost burden. Minimizing base facility requirements substantial costs sav.ngs can be accrued.

Candidate solutions include doing all at KSC, doing all at platform contractor, or doing pieces here, there and everywhere. The trades involved include such considerations as the fact that KSC space is expensive, the platform contractor might need new and or modified facilities, or that the payload contractor doesn't have capability. One good candidate solution may be as follows:

- Platform contractor performs planning function
- KSC for final integration only
- Platform contractor does subintegration on pallet on 90 percent of the equipment
- Payload contractor and/or sponsor does alignment and calibration of sensors (payloads) and certifies.

The benefits of this approach include no new facilities, no facilities modifications, and everyone using their special capabilities as opposed to training unintimidated groups.

6.3.8 Example Accommodations in L&M for SIRTF Payload

L&M requirements will differ for each payload. In the actual program the platform contractor will optimize the L&M approach for each payload based on a trade analysis. This technique will be to analyze the specific requirements and screen the L&M capabilities of the experimenter; MDAC, NASA, and other support contractors to formulate an optimum approach for each payload.

For the SIRTF, requirements for L&M would include (1) design assistance in making optical element changeable in orbit, (2) stocking various optical and other payload elements for spares and modification, and (3) cryogens and consumables support such as terrestrial delivery schedule, accommodation on M&S modules, and on-orbit changeout and handling.

Candidate solutions may include design assistance such as S&M design manual and design consultants (or both), multiple configuration L&M modules (tailored to task), stocking (platform contractor for payloads or payload contractors for themselves), and cryo and consumable support (platform contractor does for everyone, payload contractors do for themselves, or NASA does for all). Trade aspects would include cost, facility requirements, smooth work flow, L&M module capability range. One good solution for SIRTF may include:

- Design consultant for optical replacement - goes right to essence of problem and solves.
- Small L&M module - full cargo bay.
- Payload contractor supplies optical elements - he has them in his lab.
- Platform contractor supplies all consumables except cryo - he is doing it for everyone.
- NASA provides cryo - they have the plant.

In support of such activities the platform contractor performs integration for flight, management of resources, establishes crew training requirements, and NASA would perform crew training.

6.3.9 Service Module

There are various concepts being considered for this function as indicated in Figure 6.3.9-1. The configuration will be selected after a thorough study of the needs of all elements to be serviced. Figure 6.3.9-2 illustrates the flow of activities envisioned for such a service module.

6.3.10 In-Flight Experiment Modifications

Little data exists on the potential for maintenance or refurbishment for candidate platform payloads. However, the following estimate of such activity for a number of payloads has been developed for reference purposes. See Table 6.3.10-1.

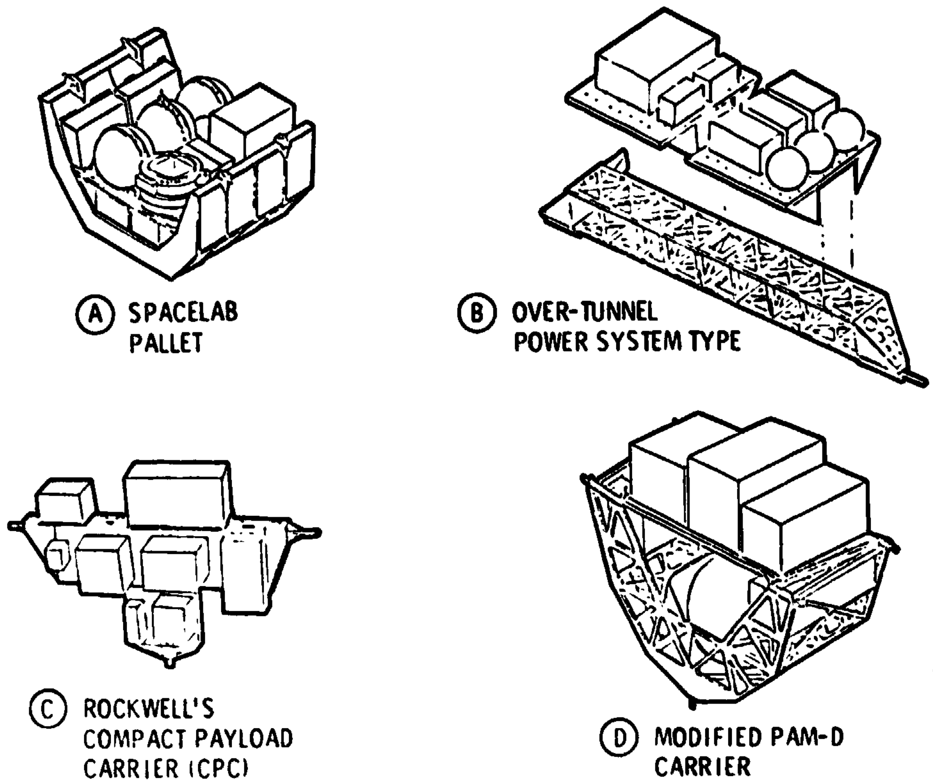


Figure 6.3.9-1 Service Module Options

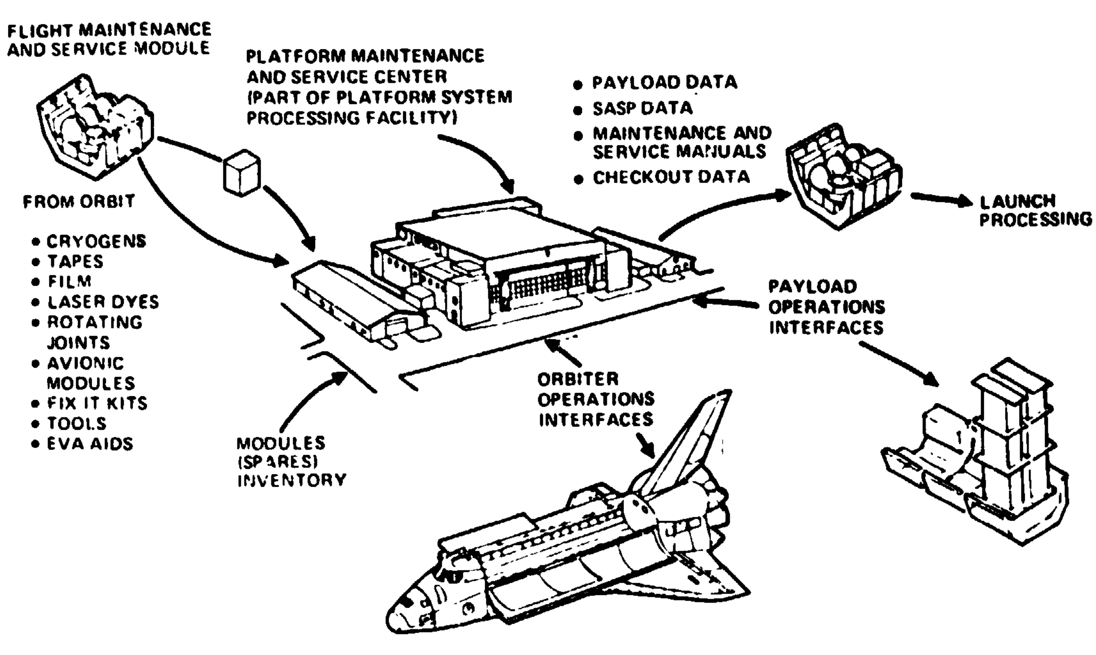


Figure 6.3.9-2 Platform/Payload Maintenance and Servicing

Table 6.3.10-1 In-Flight Experiment Modifications

The following are examples of typical on-orbit experiment modifications.

● EXAMPLE NO. 1: SP-3, Lyman Alpha/White Light Coronagraph

EXPERIMENT CHANGE	HARDWARE CHANGES REQUIRED	RECURRENCE
Increase Wavelength Selectivity	Add Additional Filter. May Require New Filter Assembly	Perhaps Once During the Mission
Increase Wavelength Range	Add Additional Filters May Require New Filter Assembly	Perhaps Once During the Mission
Increase Magnification of Solar Disk	Replace Optics	Perhaps Once During the Mission

(Potential Maintenance Areas)

- Film Transport Mechanism
- Filter Wheel

● EXAMPLE NO. 2: SPP-4, Plasma Diagnostic Package

(The Probability that Changes Will be Requested is Small)

Extension of Energy Range	Modification of Detector System	Once in 3 Years

(Potential Maintenance Areas)

- No Real Problem Areas
- Failure of Electronic Components, Particularly High Voltage

- EXAMPLE NO. 3: R-13, Lidar Temperature Sensor

Increased Vertical Resolution	Replace or Modify the Laser	Once Per Two Years As State-Of-The-Art Increases
Increased Measurement Accuracy	Replace or Modify the Laser, and Modify High Voltage System	Once Per Two Years
Increased Measurement Sensitivity	Replace Optics. Also Replace Detectors with Lower-Noise Detectors	Once Per Two Years

(Potential Maintenance Areas)

- Laser Failure (Likely)
- Failure of High Voltage Components (Likely)
- Degradation of Optics, Requiring Replacement (Likely)
- General Maintenance, Calibration, and Alignment Adjustments Required (Probably Once a Month, but Dependent Upon Duty Cycle)
- Degradation of Detectors

- EXAMPLE NO. 4: Lamar

Increased Spatial Resolution	Replacement or Major Modification of Detector Array. Also, Increased Stability and Pointing Accuracy Requirements	Roughly Once Per 3 Years
Increased Energy Range	Probably Requires Only Minor Modification of the Electronics Unless a Major Increase in Energy Range is Requested	Roughly Once Per 3 Years
Increased Energy Resolution	Modification of Data Processing Electronics	Roughly Once Per 3 Years

(Potential Maintenance Areas)

- No Real Problem Areas
- General Preventive Maintenance, and Calibration (Probably Each 6 Mo.)

- EXAMPLE NO. 5: AST/TEL

Increase Sensitivity	• Replace Mirror with One of Larger Diameter. Possibly Replace Entire Optic System • Replacement of Detectors with Lower-Noise Detectors as State-of-the-Art Increases	Roughly Each 3-4 Years
Increase Capability to Study Specific Stars in Detail	Increase Pointing Capabilities (Angular Range, Accuracy, Integration Time). Replace or Upgrade the Pointing System	Roughly Each 3-4 Years
Increase Spectral Resolution	Add Additional Detectors and Filters	Once Per Year

(Potential Maintenance Areas)

- Alignment of Optical System
- Detector Degradation
- Pointing System (Failure; or Degradation in Pointing Accuracy, Stability)
- Extreme Sensitivity to Vibration

6.4 EXTRA-VEHICULAR ACTIVITY*

6.4.1 EVA - A Routine Service to SASP Payloads

We have come to a point in the United States space program where EVA is an acceptable, qualified activity for support of on-orbit payloads. EVA support for SASP scientific experiments will be provided during routine periodic visits of Shuttle to the Power System/SASP facility. During these visits it is anticipated that EVA will also be used for maintenance and servicing of the basic PS/SASP facility, thus distributing the costs across the facility and payload.

Figure 6.4.1-1 is an artists concept showing the Power System and SASP docked to the Shuttle with an EVA crewman performing EVA in the vicinity of one of the SASP payloads and assisted by the Shuttle Remote Manipulator System (RMS). In the various utilization modes available, EVA is a feasible alternative to remote operations for satisfying all anticipated experimenter on-orbit support needs.

EVA will be performed by astronauts intensively trained in EVA basics and practiced on the EVA procedures for each specific mission. Normally two of the astronaut crewmen on each Shuttle flight will be EVA trained.

6.4.2 EVA Requirements Prospects

Many SASP operations are candidates for EVA implementation. Some of the more vital ones are listed below.

- Film and Tape Replacement
- Focal Plane Instrument Exchange
- Subsystem Equipment Exchange
- On-Orbit Checkout
- On-Orbit Maintenance (Scheduled and Unscheduled)
- Payload Deployment/Retrieval/Exchange
- Gas/Cryogen Replenishment
- Observation/Inspection of Experiments

* A briefing on this material was developed and presented to the platform user group by special request.

- Experiment Calibration/Alignment
- Contingency Operations

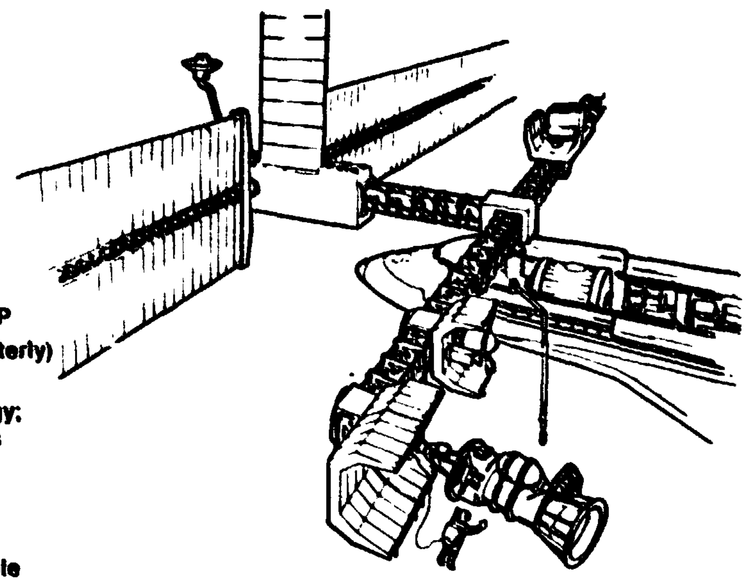


Figure 6.4.1-1 EVA - Routing Service to SASP Payloads

These options span the range of possible ways of achieving SASP operational requirements, including EVA. The options considered for each of the operational requirements are as follows:

- Remote Control from AFD Panel
- Remote Control from Ground
- RMS Controlled by Crewmen
- TRS Operated from AFD
- EVA Alone
- RMS with EVA Assist
- EVA Crewman on MRWS attached to RMS Boom
- EVA Crewman on MMU

Four of the options utilize EVA, either alone or in combination with other devices such as the RMS, MRWS, and MMU. Each of these EVA modes has both advantages and limitations which are summarized below.

EVA

- Prebreathing Time
- Produces Contaminants
- Protective Design of Payloads and Subsystems
- Scheduling to Avoid South Atlantic Anomaly
- Additional Consumables
- Two Crewmen Required

MRWS

- Development Status Uncertain
- RMS Unavailable for Other Functions

RMS

- Limited in Reach
- Grasping Fixture on Manipulated Objects
- Special End Effectors for Non-Standard Operations
- RMS may be Otherwise Employed

MMU

- Weight and Volume in Cargo Bay
- Requires Attachment Fittings on SASP/Payloads

Figure 6.4.2-1 illustrates the manned-accessibility designed into the central support module of the Platform.

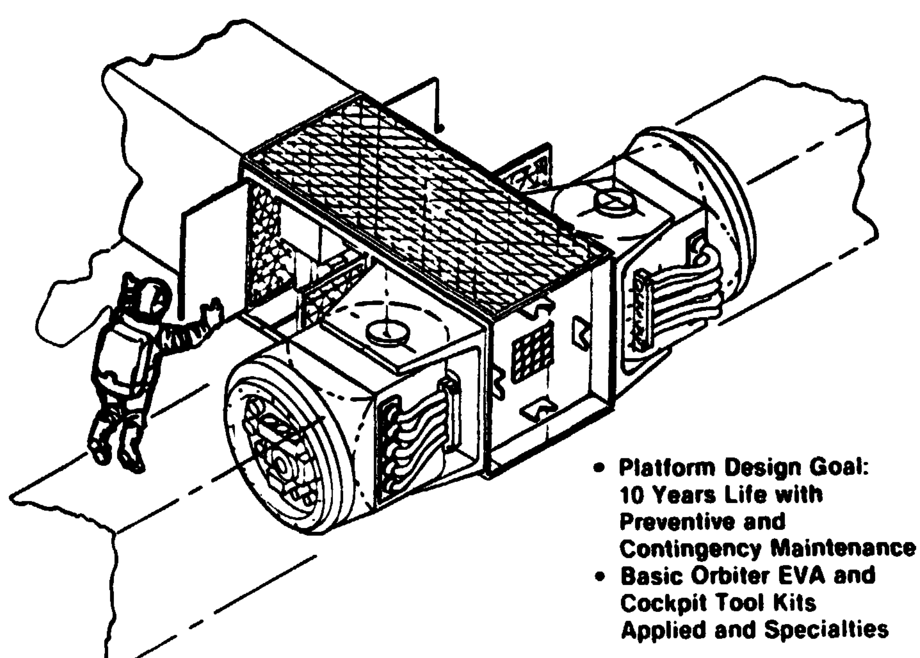


Figure 6.4.2-1 EVA Servicing of Platform Support Module

6.4.3 EVA Parameters

The major EVA parameters which must be considered in trade studies are summarized in the boxes in Figure 6.4.3-1. The crew/mission time parameter is important in assessing time required for particular EVA applications. In all of the EVA modes two crewmen must be suited even though only one may be actively employed. The 3 hour prebreathing time is a NASA specified duration as is the limitation to 6 hours/day, although the suit ECS system also limits a particular EVA sojourn to approximately 6 hours. Suite drying time is included here since it may dictate the minimum time between EVA sojourns.

CREW/MISSION TIME

- 2 EVA CREWMEN; 3 IF RMS USED
- 3 HOURS PREBREATHING OVERHEAD
- EVA LIMITED TO 6 HOURS/DAY
- PRE- AND POST-EVA OVERHEAD TIME
- SUIT-DRYING TIME

DESIGN

HANDRAILS AND RESTRAINTS
DESIGN FOR EVA SAFETY
PROTECT INSTRUMENTS FROM EVA CONTAMINATION
DESIGN COMPONENTS FOR EVA HANDLING

Figure 6.4.3-1 EVA Parameters

Utilization of EVA does impose some design constraints, both on the SASP platform and the attached payloads as indicated in the box at the bottom of the page.

6.4.4 EVA Considerations for Cryo-cooled Payloads

Two primary areas of potential EVA support in these types of payloads are sensor and cryogen/replacement. Sensors and coolant are untimely integrated in these type of payloads. Therefore, if periodic sensor replacement is desired, specific EVA access to and simple provision for coolant surface decoupling and removal of sensors is required. The latter may increase the challenge of providing extremely low temperature cooling; however, the cost of such a feature must be traded against the level of interest in exchanging sensors. EVA is felt to be more appropriate than RMS removal of such critical equipment.

Conversely, the replacement of depleted cryogen tankage is currently felt to require remotely-controlled operations such as RMS or automated cartridge-type tank replacement, with EVA monitoring and selective assist in preparation or securing steps such as removel and replacement of leak-proof enclosures around remotely-controlled couplings.

6.4.5 Emerging SASP EVA Concept

The EVA concept which is developing for SASP operations recognizes that EVA is a qualified candidate, but only one of several which must be considered. It is perhaps the only method for backup performance of operations in which the primary method fails, such as retraction or deployment of appendages. (See Figure 6.4.5-1.)

ASSESSMENT

- EVA IS A QUALIFIED CANDIDATE FOR CONDUCTING ON-ORBIT PAYLOAD SUPPORT FUNCTIONS
- EVA REQUIRES MORE CREW TIME AND MORE CREW TRAINING
- EVA IMPACTS PAYLOAD DESIGN SIGNIFICANTLY

PRELIMINARY CONCLUSIONS

- EACH SPECIFIC OPERATION MUST BE ASSESSED EARLY SO THAT DESIGN IMPACTS CAN BE INCORPORATED
- EVA CAN BE BENEFICIAL IN EXPERIMENT/PAYLOAD EXCHANGE OPERATIONS
- EVA BEST METHOD FOR MOST BACKUP CONTINGENCY OPERATIONS

Figure 6.4.5-1 Emerging SASP EVA Concept

6.4.6 EVA by Skylab Crew - Key to Mission Success

The difference between planned Skylab EVA (29 man-hours in 6 EVA periods) and actual EVA (82.5 man-hours in 10 EVA periods), as shown in Figure 6.4.6-1 illustrates not only the effectiveness of EVA, but also its flexibility. Most of the 13 unplanned in-flight repair tasks were performed at locations where workstations had not been provided, to which pre-planned translation paths were not available, and at which crew and equipment restraints were non-existent.

Deployment of the OWS solar array and thermal shield, as well as installation of the rate gyro package, are dramatic in that failure to accomplish any one of them could have meant loss of the mission. Of almost equal significance, however, are the unplanned EVA tasks which saved numerous experiments from early failure and contributed to the scientific success of the mission. The illustrations on the next two pages depict Skylab locations where major EVA activities were performed.

- **Scheduled EVA—29 Man-Hours (6 EVA Periods)**
  - **ATM Film Retrieval**
  - **DO 24 Sample Retrieval**
  - **S230 Collector Retrieval**
- **Unscheduled EVA—53.5 Man-Hours (10 EVA Periods)**
  - **Deploy OWS Solar Array**
  - **Deploy Twin-Pole Thermal Shield**
  - **Install Rate Gyro Cable**
  - **Repair Charger Battery Regulator Module (CBRM)**
  - **Repair S193 Antenna**
  - **Replace S082A Film Magazine**
  - **Secure S054 and 5082A Aperture Door Open**
  - **Repair S054 Filter Wheel**
  - **Clean S052 Occulting Disc**
  - **Install and Retrieve Samples**
  - **Install and Retrieve S149 Experiment**
  - **Install, Operate, and Retrieve T025, S020, and S201 Experiments**
  - **Remove S055, S056, and S082A Ramp Latches**
  - **Obtain Temperature of S020 Experiment**
- **18 Extra Mission Objectives**
- **13 In-Flight Repair Tasks**

Figure 6.4.6-1 EVA by Skylab Crew - Key to Mission Success

6.4.7 EVA Equipment - Extravehicular Mobility Unit (EMU)

Figure 6.4.7-1 illustrates some of the equipment comprising the Shuttle EVA capability. The Shuttle EMU, illustrated on the facing page, is an anthropomorphic pressure suit continuing its own back mounted life support system. Compared with some earlier suits, such as the Gemini suit, an umbilical is not required. Not shown in this illustration is the Liquid Cooled Ventilation Garment which is worn under the basic pressure suit.

The Shuttle airlock through which the EVA crewman exits and enters the Shuttle pressurized middeck, may be mounted inside the crew compartment or external in the payload bay attached to the forward bulkhead. Support equipment in the payload bay includes handrails for translating to various payload bay locations, lights, TV cameras, EVA tools, and the Shuttle Remote Manipulator System (RMS) which is discussed in some detail later.

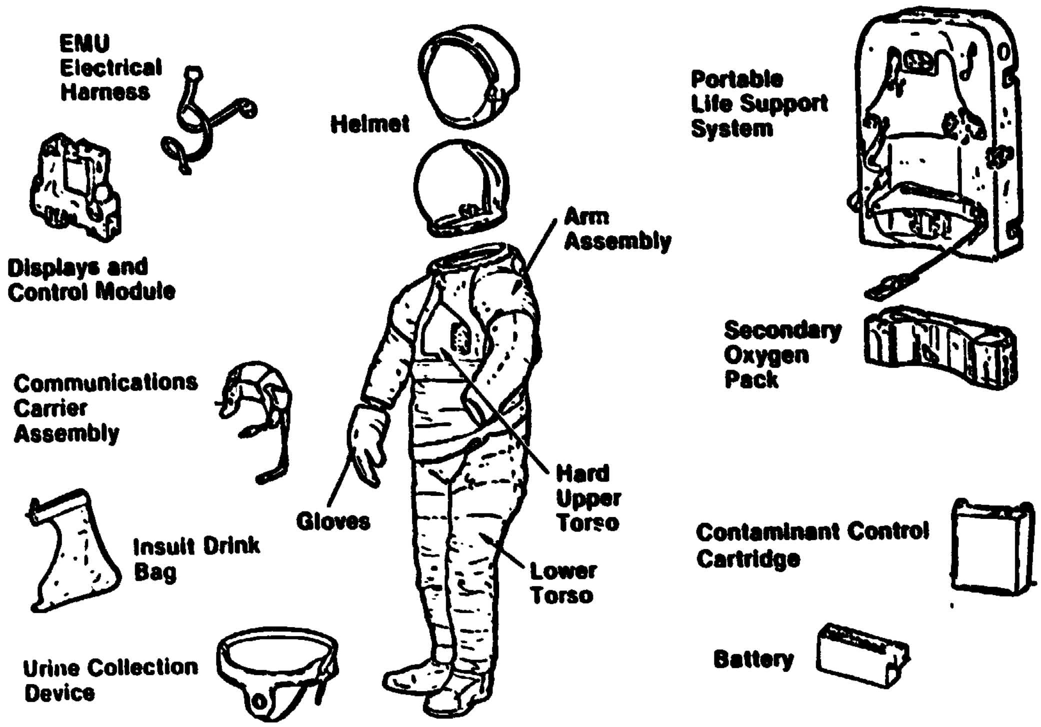


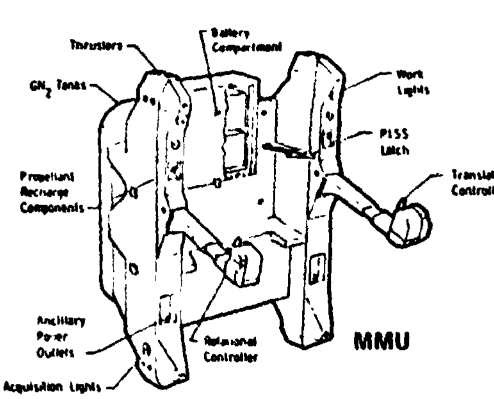
Figure 6.4.7-1 EVA Equipment - Extravehicular Mobility Unit (EMU)

Two EMU's are carried on each Shuttle flight. They will ordinarily be used by the Pilot and Mission Specialist, both of whom will have extensive training in EVA. The EMU can support 6-hours continuous EVA at an average metabolic rate of 1,000 BTU per hour. Suit pressure is nominally 4 psi and thus with a 14.7 psi Shuttle cabin prebreathing of approximately three hours is required. Following a 6-hour EVA the suit can be recharged in one hour.

6.4.8 EVA Equipment - Manned Maneuvering Unit (MMU)

The MMU is a propulsive modular backpack device used with the Shuttle EMU to provide EA working range and accessibility beyond the reach capabilities of the RMS. As illustrated and described in Figure 6.4.8-1, the MMU is designed to interface with the EMU and as such its continuous operating time is constrained by the 6 hour per EVA limit of the EMU. To a large extent the EMU is a self-contained work station since it provides worksite lighting, outlets for power tools if needed, and a capability for automatic attitude hold at the work station. However, if large forces and torques must be exerted at the work station, additional worksite restraints must be provided.

The MMU will be flown only on those Shuttle flights where its utilization has been planned preflight. One or two MMU's can be carried and they are stowed in the forward part of the payload bay on the port and starboard sides.

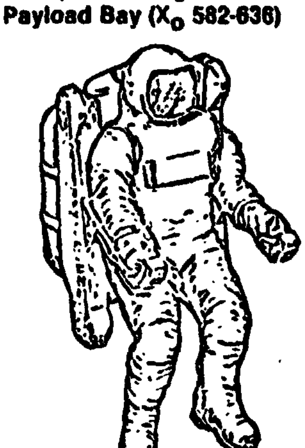


CHARACTERISTICS

- Development Status: Production
- Weight: 240 lb
- Propulsion: Noncontaminating Dry GN_2
- Control: 6 DOF Manual Translation and Rotation Automatic Attitude Control
- Power: 2-28 VDC Outlets
- Lighting: Two Spot Worklights
- Stowed in Payload Bay (X_0 582-636)

PERFORMANCE

- Day or Night Operation
- Rotation Acceleration: 10° per sec^2
- Translation Acceleration: 0.3 FPS^2
- Normal Operating Range: 300 ft
- Velocity: 1-5 FPS
- Arms Fold Down for Clearance
- Donning Requires ≤ 10 Minutes
- Untethered Translation
- Can Transport Packages of Several Hundred Pounds



MMU Donned

Figure 6.4.8-1 EVA Equipment - Manned Maneuvering Unit (MMU)

6.4.9 EVA Equipment - Open Cherry Picker MRWS

Manned Remote Workstation (MRWS) is a generic term for a family of manned work platforms, the first of which is the Open Cherry Picker (OCP), and includes closed work modules, railed work stations, and free flyer work stations. These future versions are planned primarily to support large space construction activities.

The OCP, illustrated in Figure 6.4.9-1, attaches to the standard RMS end effector and its work volume is therefore constrained by RMS reach. The EMU suited crewman is restrained on the Platform by a standard Shuttle foot restraint system. He operates the work station, including the RMS itself if desired, from a control and display console located on the work station. The OCP work station is completely self-contained, providing electrical power via the RMS end effector, work site lighting, bins for EVA tools, and a payload

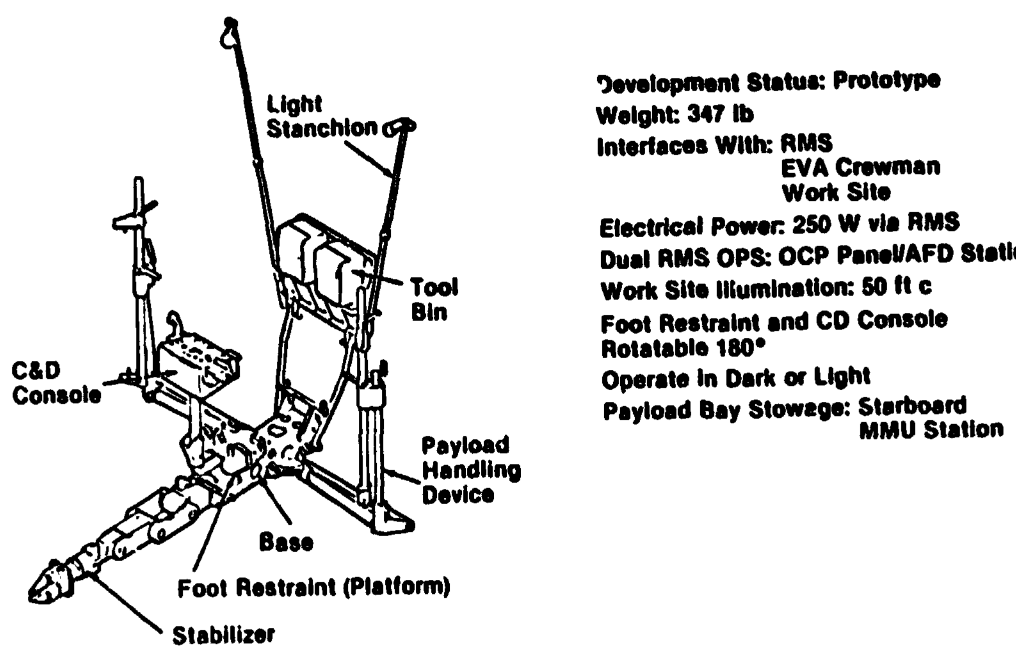


Figure 6.4.9-1 EVA Equipment - Open Cherry Picker MRWS

handling device for securing and transferring packages such as replacement instruments or subsystem components. An electro-mechanical manipulator (stabilizer) is provided to secure the OCP work platform to the work site. A picture of the prototype Open Cherry Picker is shown in Figure 6.4.9-2.

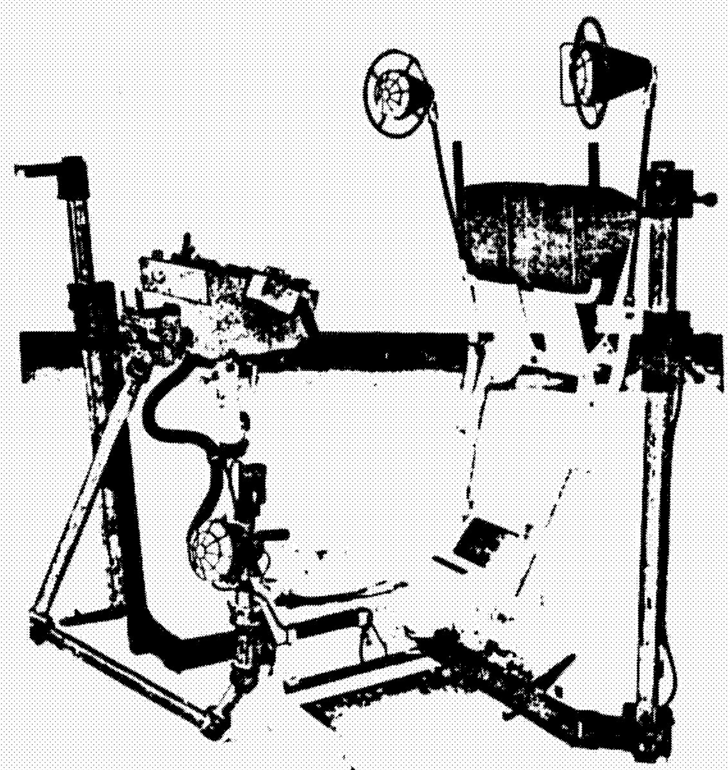


Figure 6.4.9-2 Prototype of Open Cherry Picker MRWS

6.4.10 Utilization Mode Selection Criteria

Some of the considerations which must be taken into account in selecting an EVA mode of utilization are shown in Figure 6.4.10-1. In some cases selection may be dictated by mission or payload configuration conditions. For example, if the payload to be accessed is beyond the reach of the Remote Manipulator arm and manual translation paths are not available, ther the MMU would

automatically be chosen. For final selection of a utilization mode the total mission must be considered; in some cases, for instance, there may not be room in the Shuttle payload bay for either an MMU or an OCP to be carried. In other cases the RMS may be required for non-EVA activities during the entire mission and may not be available to support EVA utilization modes which require it.

EMU Alone

- Lowest Cost
- Frees RMS for Other Tasks
- Requires Only Two Crewmen
- Restricted to Small Packages
- Requires Translation Path
- Requires Worksite Restraints
- Minimum Weight Penalty

EMU With RMS

- Large Package Capability
- Task Time Efficient
- Constrained by RMS Reach
- Requires Grapple Fixtures
- Requires Translation Path
- Requires Three Crewmen

EMU with MMU

- Flexibility in Range and Area ... ge
- Noncontaminating
- Minimum Restraint/Mobility Aic
- Requires No More Than Two Crewmen
- Weight Penalty
- Reduced Range and Velocity With Large Packages

EMU With RMS/OCP

- Self-Contained Workstation
- Provides a Stable Work Platform
- RMS Operation From OCP
- Minimum Obstacle Avoidance Problems
- Constrained by RMS Reach
- Minimum Design Impact
- Restricted in Payload Transport
- RMS Unavailability for Other Functions
- Weight Penalty
- Requires Three Crewmen

Figure 6.4.10-1 Utilization Mode Selection Criteria

6.4.11 Responsibilities of Payload User

For the experimenter or the space experiment facility designer who desires to use EVA to enhance mission and scientific objectives, the suggestions on the facing page (Figure 6.4.11-1) provide a minimum list of responsibilities. It is important that the user have a good understanding of the capabilities and limitations of EVA and of its various utilization modes, that he coordinate with other users and with qualified EVA experts to use EVA in the most cost effective manner, and that he include potential EVA utilization in his definition of experiment hardware and operating procedures as his planning progresses.

- **Provide Payload Definition and Operating Procedures**
- **Define EVA Requirement and Utilization Mode**
- **Plan Maximum Use of Standardized EVA Tasks**
- **Specify Available EVA Tools Where Possible**
- **Provide Special Tools and Equipment if Required**
- **Provide Special Purpose RMS End Effectors if Required**
- **Provide Payload Specific Training Articles — Gross Representations of 1-g Items and Neutral Buoyancy Items**
- **Coordinate with NASA EVA Personnel**
- **In Special Cases Provide Training at Payload Production Facility**
- **Planning Documents and Advice Available**

Figure 6.4.11-1 Responsibilities of Payload User

The NASA astronauts provided on PS/SASP servicing flights will be highly trained in EVA as a technology in standard EVA procedures and in the use of standard Shuttle EVA tools and equipment. It is thus desirable, from a training efficiency standpoint, that users specify their EVA requirements to include standard procedures and standard tools and equipment to the maximum extent possible.

The following documents provide further information and insights into EVA equipment, procedures, and guidelines:

- Space Shuttle EVA Opportunities, NASA JSC 11391
- Shuttle Flight Operations Manual - EVA Systems, NASA JSC 12770, Volume 15.
- Shuttle EVA Description and Design Criteria, NASA JSC 10615
- User's Guide - Manned Maneuvering Unit, Martin Marietta Corporation

Section 7
DEMONSTRATION TEST

In order to minimize SASP program development risks a demonstration test program will be required. This test program will include early ground development testing at various levels of subsystem assembly and will progress into selected flight demonstration tests of critical mechanisms, structures, and associated operations.

7.1 GROUND TEST PROGRAM

During the development and qualification of the SASP subsystem hardware the required flight performance will be demonstrated via ground test verification wherever practical. Ground development testing will be conducted early in the hardware development phase for those components and subsystems where space-qualified hardware is not available or when the SASP application and/or environment is significantly different than that for which the hardware had previously been qualified. Wherever possible, the available test and operational data for flight-qualified hardware will be used to qualify that hardware for SASP application. This will be accomplished by demonstrating similarity of application or by extrapolation of existing data via analytical techniques. Development flight testing is proposed only where ground simulation is inadequate to give the necessary confidence for flight performance.

The ground test program being planned for SASP will be similar to the design development and qualification test programs used effectively on manned space flight programs. The development/qualification test approach will qualify a component/equipment during a development test if the test specimen is sufficiently representative of the flight article and is subjected to test

levels meeting qualification test requirements without failure. Development/qualification testing, together with evaluation and qualification of components/equipment by analysis and similarity comparisons to previously qualified hardware, provides the opportunity to develop SASP at the least possible cost while taking minimum technical risks.

Table 7.1-1 shows the preliminary test requirements generated for the SASP development/qualification program. This table shows the requirements to be satisfied at each level of system assembly.

7.2 FLIGHT TEST PROGRAM

Certain portions of the platform systems will require flight demonstration testing to verify the critical parameters of the rotational mechanisms, expandable truss, berthing ports, and the structural free play effects in a zero-g environment. Test results will be used to verify/update the analysis, ground tests, and the assumptions made during the design phase. Figure 7.2-1 presents the general flight demonstration test requirements. A typical flight demonstration test program is presented below.

The flight demonstration test article (Figure 7.2-2) will be stowed on a single pallet, unloaded from the pallet with the RMS, and assembled onto the Orbiter berthing port. The test demonstration carrier pallet will then be berthed onto the test article berthing mechanism. This will verify the berthing port latching systems and the RMS latching system. The carrier pallet will house the necessary test equipment to collect and redistribute data to the Orbiter. The test setup requirements and instrumentation are shown in Table 7.2-1 and Figure 7.2-3. Various portions of this test can be performed in parallel with other cargo bay experiment operations.

	[illegible]																			Qualification																
	[illegible]																			Test requirements																
NOMENCLATURE	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Acoustics
SASP-SECOND ORDER WITH TRAIL ARM	X																																			
STRUCTURE																																				
STANDOFF TRUSS (GR/EP)	X	X	X				X	X			X			X	X	X				X	X	X	X			X	X			X						
LONGERONS		X	X	X	X			X	X		X																									
DIAGONAL		X	X	X	X			X	X		X																									
END FRAMES																																				
FITTINGS																																				
TUBE ENDS																																				
CROSS ARM TRUSSES (GR/EP)	X			X	X		X	X	X		X			X	X	X			X	X			X	X		X	X	X		X		X	X	X		
SUBSYSTEM MODULE (AL/MLI)							X	X			X					X					X	X		X		X	X			X						
TOP & BOTTOM																																				
SIDES & BULKHEADS																																				
DOORS																																				
RADIATOR SUPPORTS							X											X								X	X	X		X						X
END HOUSINGS																										X	X	X		X						X
BERTHING		X	X	X	X		X	X			X			X	X	X			X		X	X	X	X		X	X			X			X	X		
ACTIVE																																				
PASSIVE																																				
UMBILICALS		X	X	X	X		X	X			X			X	X	X			X		X	X	X	X		X	X			X			X	X		
ACTIVE																																				
PASSIVE																																				
JOINTS																																				
± 180 ARM ROTARY		X	X	X	X		X				X			X					X		X	X	X	X		X				X			X	X		X
SUPPORT STRUT		X	X		X		X	X	X		X			X		X								X		X	X	X		X			X	X		X
90° ARM HINGE		X	X	X	X		X				X			X					X		X	X	X	X		X				X			X	X		X
ORBITER BERTHING BOOM	X	X	X	X	X		X	X			X			X		X			X	X			X	X		X	X			X			X			X
OUTER SHELL																																				
INNER SHELL																																				

Table 7.1-1 Preliminary SASP Test Requirements

	Development Test requirements																			Qualification Test requirements																
NOMENCLATURE	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Acoustics
JACK SCREW & MECH.																																				
ORBITER BERTHING-PASSIVE																																				
ORBITER UMBILICAL-PASSIVE																																				
SUBSYSTEM TO BOOM ATTACH.																																				
HARDWARE																																				
±180° ROTARY JOINT				X	X		X				X			X					X		X	X	X	X		X				X			X	X		X
TRAIL ARM	X			X	X		X	X			X			X		X			X	X			X	X		X	X			X			X			X
TRUSS																																				
ROD SUPPORT																																				
END HOUSING																																				
BERTHING PORT		X	X	X	X		X	X			X			X	X	X			X		X	X	X	X		X	X			X			X	X		
ACTIVE																																				
PASSIVE - SM TO TA																																				
PL EXTENSION IF PORT																																				
UMBILICALS		X	X	X	X		X	X			X			X	X	X			X		X	X	X	X		X	X			X			X	X		
ACTIVE																																				
PASSIVE																																				
POWER DISTRIBUTION																																				
MINI ARM																																				
30 VDC DISTRIBUTOR					X		X														X			X		X	X									
120 VDC DISTRIBUTOR (3)					X		X														X			X		X	X									
MINI CABLES				(1)																																
STANDOFF MOD/SUBSYSTEM																																				
30 VDC DISTRIBUTOR					X		X														X			X		X	X									
120 VDC DISTRIBUTOR (3)					X		X														X			X		X	X									
400~ DISTRIBUTOR																																				
400~ INVERTERS					X		X						X	X																						
STANDOFF CABLES				(1)																																

Table 7.1-1 Preliminary SASP Test Requiremetns (Continued)

NOMENCLATURE	Development Test requirements																			Qualification Test requirements																
	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Acoustics
CENTER ARM																																				
30 VDC DISTRIBUTOR					X		X														X			X		X	X									
120 VDC DISTRIBUTOR (3)					X		X														X			X		X	X									
ARM CABLES				(1)																																
ORBITER I/F CABLES				(1)																																
TRAILING ARM																																				
30 VDC DISTRIBUTOR					X		X														X			X		X	X									
120 VDC DISTRIBUTOR (3)					X		X														X			X		X	X									
400~ DISTRIBUTOR					X		X														X			X		X	X									
TRAIL ARM CABLES				(1)																																
THERMAL CONTROL																																				
PUMP PACKAGES (2)																																				
DISCONNECTS					X		X														X	X		X		X	X									
LINES (2)																																				
FLEX LINES					X		X														X	X		X		X	X									
CONTROL VALVES					X		X														X	X		X		X	X					X		X		
COLD PLATE (2)																																				
RADIATOR (4)				X	X		X											X			X	X		X		X	X									
JOINTS					X		X														X	X		X		X	X									
AVIONICS																																				
SENSORS (LOC., TEMP & PRESS)					X	X	X						X											X	X	X						X				
RIU'S (2)																																X				
CONTROL UNITS (DRIVE ELECTRONICS - JOINTS)				X	X		X						X								X	X	X	X		X	X					X		X		
WIRING				(1)																																
HI RATE RECORDER				X	X		X						X								X	X	X	X		X	X					X	X	X		
DATA MULTIPLEXER				X	X		X						X								X	X	X	X		X	X					X	X	X		
EXPANDER UNIT (FOR RIU'S) (2)																																X				

Table 7.1-1 Preliminary SASP Test Requirements (Continued)

NOMENCLATURE	Development Test requirements																			Qualification Test requirements																
	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load		EMI	Performance	Life cycle	Ultimate	Acoustics
VIDEO SWITCH (2)																								X		X						X	X			
BUS COUPLER (2)																								X		X						X	X			
POINTING AND CONTROL																																				
MAGNETIC TORQUERS (5)																							X	X		X	X					X	X			
TORQUER ELECTRONICS (5)																							X	X		X	X					X	X			
ROTARY JOINT ENCODERS					X	X	X	X					X	X				X					X	X		X	X					X	X			X

(1) Will test cable insulation for outgassing properties
(2) Assume this hardware will be qualified for Orbiter and/or spacelab.
(3) Development testing at the component level may also be required.
(4) Partial Panel Onl,
(5) Qualified for Space Telescope

Table 7.1-1 Preliminary SASP Test Requirements (Continued)

- ROTARY JOINTS
  - POWER REQUIRED TO DRIVE
  - THERMAL GRADIENTS AND THEIR EFFECTS
  - FREE-PLAY EFFECTS
  - DYNAMIC LOADING CAUSED BY START AND STOP
  - NOISE GENERATION
  - POINTING ACCURACY
- EXPANDABLE TRUSS STRUCTURE
  - EXPOSE TO THERMAL ENVIRONMENTS AND DEPLOY AND RETRACT
  - RECORD POWER REQUIRED TO DEPLOY AND RETRACT
  - VERIFY THE COOLANT AND CABLING RESTRAINTS CAUSED BY ZERO G
  - VERIFY DISTORTION (THERMAL)
- BERTHING PORTS
  - DETERMINE LATCHING AND UNLATCHING LOADS AND DYNAMIC EFFECTS DURING UNLATCHING
  - DETERMINE UMBILICAL LATCHING AND UNLATCHING LOADS AND POWER CONSUMPTION
  - VERIFY ACCURACY REQUIREMENT FOR ALIGNMENT BY MEANS OF CSTV UTILIZING THE RMS
- FIRST-ORDER PAYLOAD SUPPORT STRUCTURE
  - VERIFY ROTATIONAL ACCURACY AND DYNAMIC EFFECTS DURING START AND STOP UNDER THERMAL SOAK CONDITION
  - RECORD GEAR TRAIN NOISE TRANSMISSION
  - POINTING ACCURACY AT EACH STOP LOCATION

Figure 7.2-1 Flight Demonstration General Test Requirements

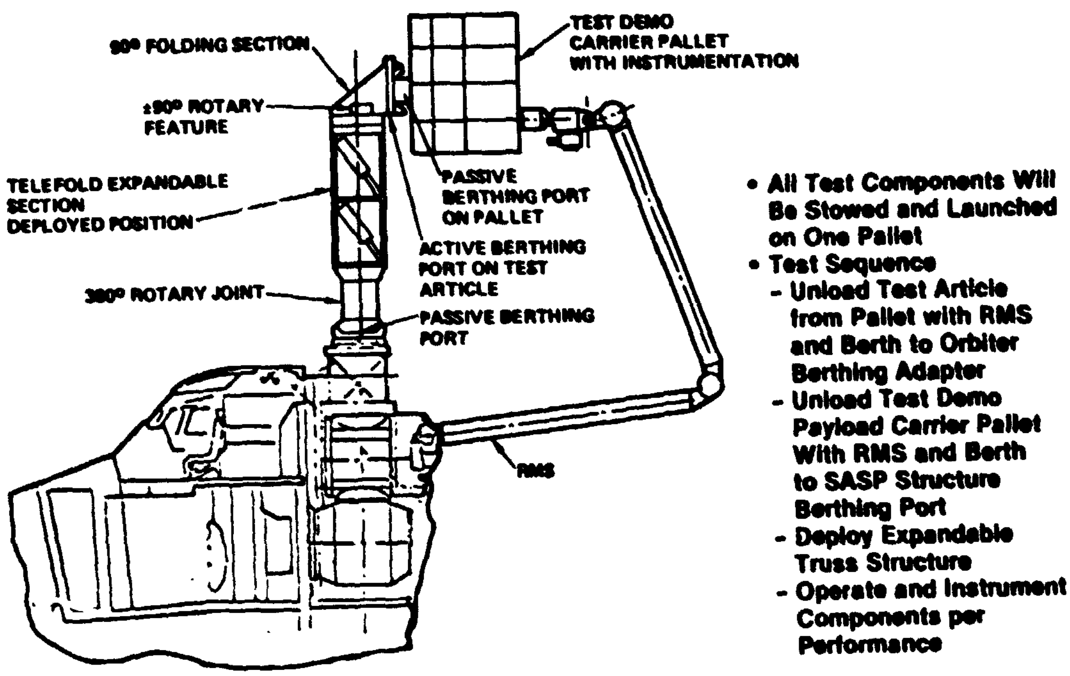


Figure 7.2-2 Flight Demonstration Test Article

TEST ENVIRONMENT	METHOD OF INDUCING ENVIRONMENT	TEST DATA REQUIREMENTS	*INSTRUMENTATION	LOCATION OF INSTRUMENTS
THERMAL	• ORBITER ORIENTATION TO SUN • ROTATIONAL FEATURE OF TEST ARTICLE	• THERMAL GRADIENTS • DEFLECTIONS • PRE & POST ANGULAR ROTATIONAL ERROR • DEPLOYMENT	• THERMOCOUPLES	• PALLET • ORBITER
DYNAMIC	• ORBITER VRCS	• NATURAL FREQUENCY • MODE SHAPES	• ACCELEROMETERS AND RECORDERS	• TEST ARTICLE • ORBITER • PALLET
LOADS	• ORBITER VRCS THRUSTERS • RMS • EVA	• STRAIN - THERMAL - DYNAMIC • DEPLOYMENT	• STRAIN GAUGES • DISPLACEMENT POTENTIOMETER	• TEST ARTICLE • ORBITER • PALLET

*CONTAINED IN REMOTE INTERFACE UNIT (RIU)

Table 7.2-1 SASP Flight Test Requirements, Set-up and Instrumentation

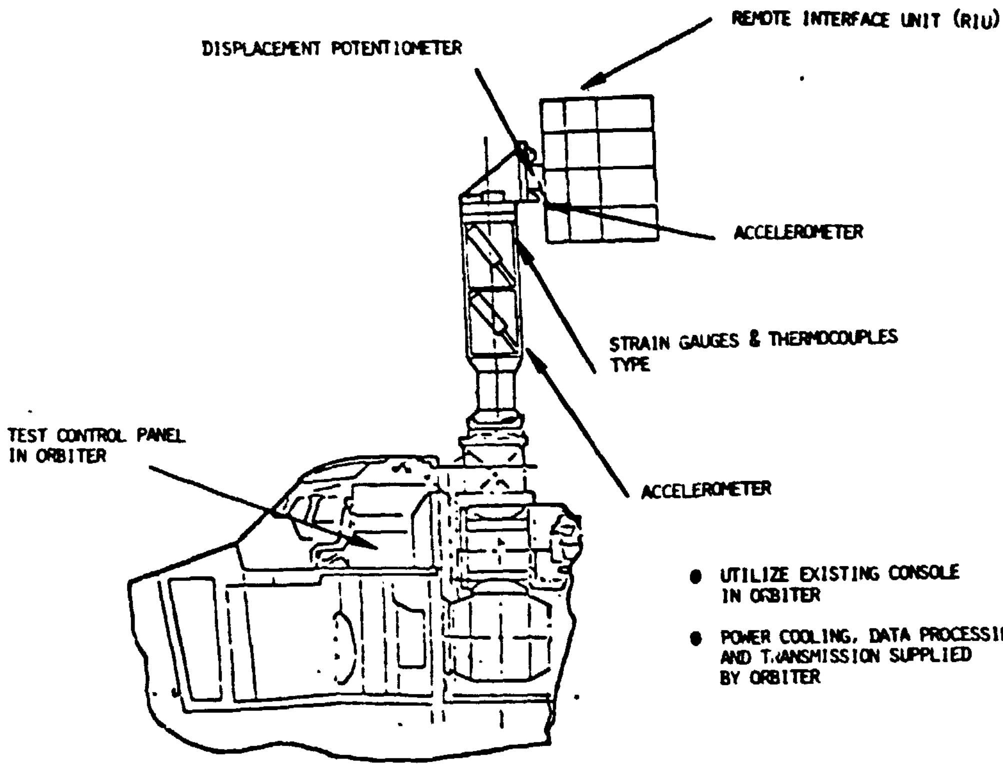


Figure 7.2-3 Demonstration Test Article Instrumentation

Additional study effort is proposed to identify additional test configurations and flight test scenarios to optimize the flight test program.

7.3 CONTRIBUTORY ROLE OF OPERATIONAL FLIGHT

- Can be final step in "performance assurance"
- Detailed malfunction prospects defined in advance
- Contingency mode options planned/trained in advance
- Crew (EVA) and equipment (tools) for contingencies
- Factional operation assumptions
- Contingency support by subsequent-dedicated flights (three-month intervals)
- System can be designed for considerable contingency flexibility to reduce need for development flight testing.

Section 8
SPECIAL EMPHASIS TASKS
(Task 8)

8.1 DATA FLOW

The purpose of this task was to analyze the data flow requirements between SASP payloads and the investigators and other users, the mission operations requirements, and the communications and data processing technology and resources available to ensure that the SASP communication and data management system is responsive to payload requirements and that viable approaches are identified to accommodating the overall end-to-end data flow requirements.

Overall Requirements Summary

The overall requirements for an end-to-end data system to accommodate SASP can be summarized as follows:

- Provide a data acquisition and real-time control capability for multiple payloads. Peak data acquisition rates will be as high as 120 Mbps per payload.
- Provide scientific data to the user community in a timely manner and in readily usable form.
- Accommodate the anticipated growth in the total amount of data to be acquired and processed.

8.1.1 Important Factors and Considerations

The capability of the Tracking and Data Relay Satellite System (TDRSS) is a key consideration in end-to-end data flow since it is expected that all, or nearly all, NASA spacecraft in the late 1980's will use TDRSS for ground/spacecraft communication. This capability is summarized in Figure 8.1.1-1. The overall NASA mission model, as it affects TDRSS and ground network loading,

		RETURN LINK				
		PEAK RATE	BITS/ORBIT	CONTINUOUS RATE	FORWARD LINK PEAK RATE	INTERACTIVE CONTROL CAPABILITY
	SASP NEED	220×10^6	$10^{10} - 10^{11}$	$50 - 200 \times 10^3$	10×10^3	YES
TDRSS OPTIONS	MA ONLY	50×10^3	2.5×10^8	50×10^3	10×10^3	YES
	TIME SHARED SA	312×10^6	$(312 \times 10^6) \times T$*	-	300×10^3 OR 25×10^6	NO
	$\boxed{\text{MA + TIME SHARED SA}}$	312×10^6	$(2.5 \times 10^8) + (312 \times 10^6) \times T$	50×10^3	310×10^3 OR 25×10^6	YES
	DEDICATED SA	312×10^6	1.8×10^{12}	312×10^6	300×10^3 OR 25×10^6	YES
	DEDICATED TDRS	624×10^6	2×10^{12}	624×10^6 (SMALLER % OF ORBIT)	600×10^3 OR 50×10^6	YES (PART OF ORBIT)

* T = SA TIME PER ORBIT ALLOCATED TO SASP

Figure 8.1.1-1 TDRSS Utilization Options

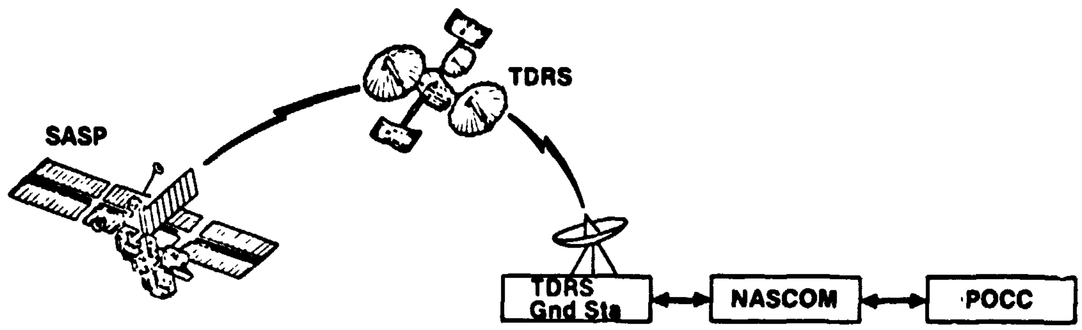
must also be considered. Ongoing work in the NASA End-to-End Data System (NEEDS) program must be recognized and considered in any SASP data flow analysis. The NEEDS program, managed by GSFC, has identified and is developing a number of system concepts that will be useful in the SASP era.

Other important factors are the mission operations concept for SASP and its payloads, the geographical location of various data users and payload command sources, and the state of technology in data handling and communications.

8.1.2 Work Accomplished

End-to-End data flow considerations have been included in the SASP data management system concept design. Specific concept features, such as payload data storage capability and an emphasis on data processing at the payload, are responsive to end-to-end data flow requirements.

An analysis of the response time capability limits imposed by TDRSS was made. The results are shown in Figure 8.1.2-1 and are discussed in a subsequent paragraph.



Response Time Delay Between Payload Event and Transmission to Payload of Command in Response to That Event

Planning Factors
- TDRSS Emergency Service Response Time — 5 Minutes
- TDRSS MA Acquisition Time — 15 Seconds
- POCC Operator Response Time — Variant
- Propagation Delays and Processing Times — <<15 Seconds

Adequacy TBD

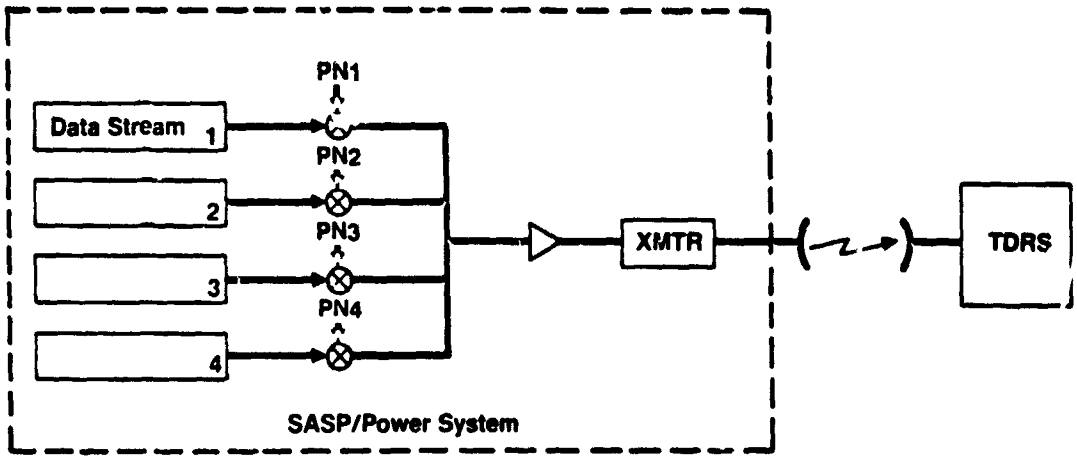
Figure 8.1.2-1 Interactive Control - Response Time

A concept for providing "real-time" downlink data rates in excess of 50 Kbps without using a dedicated single-access TDRSS channel was defined. This concept, which is shown in Figure 8.1.2-2, would make use of more than one Multiple Access (MA) Channel. The potential gains and problems associated with this approach are discussed in a subsequent paragraph.

The potential impact of a SASP on TDRSS loading, as opposed to the same payloads as free-flyers, was evaluated. Figure 8.1.2-3 summarizes the results.

8.1.3 Conclusions and Comments

The initial portion of a SASP end-to-end data flow analysis has been completed. This analysis will be continued as an add-on task to the SASP study. The initial effort has identified SASP data management system approaches that are



- Goal: Provide "Continuous" Data at Rates > 50 KBPS
- Each Data Stream is 50 KBPS or Less
- Each Data Stream has Different PN Code
- Technical Issues - (1) Mutual Interference
  (2) Power System EIRP
- Preliminary Indications Are That Up To 4 Data Streams of 50 KBPS Each Can Be Simultaneously Transmitted

Figure 8.1.2-2 Approach to TDRSS MA Usage >50 Kbps

- SASP Provides Better Utilization of Single Access Channels
  - SASP Can Dump Data From Several Payloads in One SA Schedule Block - Thereby Saving Antenna Slew/ Acquisition time
  - SASP, With a Spacelab Data Recorder (or Better) Can Dump Data Much Faster Than Most Free-Flyers
  - User Charges for SA Channels will be Reduced, and Data Loss Probability will be Reduced by use of SASP With its More Effective Use of TDRSS.
- SASP Provides a Better Capability for MA Channel Use
  - Higher EIRP Needed for MA Channel Use - Not Attractive for Free-Flyers

Figure 8.1.2-3 SASP vs Free Flyers - TDRSS Utilization

important in relation to end-to-end data flow and has suggested that TDRSS capabilities to support payload real-time interactive control requirements may be marginal, both in respect to real-time downlink data rates and in response time capabilities.

It has been shown that a SASP has potential advantages over the same payloads as free-flyers in the efficient use of the TDRSS resource. Continuation of the end-to-end data flow study effort is important to quantify system loading, to identify technology constraints, and to better define user data interfaces.

8.1.4 Historical Factors

The quantity of data that is handled by the NASA data network has grown as the result of increased level of space activity, increasingly complex experiments, and increasing electronics capability. The network, as of the 1978 time period, handled approximately 10" bits per day. It has been estimated that this will increase by an order of magnitude early in the Shuttle era. The TDRSS will allow in excess of 10^{13} bits per day to be communicated to the ground

Processing of the data has been a major problem for some programs in the past. On some programs, a large portion of the acquired data has never been examined by the user. Other programs have experienced excessive delays between data acquisition and availability of the data to the user. Time and money have been spent acquiring and processing data that was later determined to be either unwanted or unusable.

8.1.5 NASA End-to-End Data System (NEEDS)

As a result of these historical factors, NASA initiated the NEEDS program to develop concepts and demonstrate technology to support future NASA data system

development. This program addresses all data system functions from the sensor to the user interface, including the control of the payload and sensor. The objectives of NEEDS are to provide the system concepts, techniques, and technology which will increase the end-to-end data system responsiveness, reduce the relative cost of extracting information from space data, and increase the degree of standardization throughout the system.

The NEEDS program has adopted the following principles which characterize the NEEDS concept:

1. Data and Information Autonomy - Data will be autonomous and self-contained at the source.

2. Spacecraft and Instrument Autonomy - Spacecraft and instruments will be capable of operating without external intervention for extended periods.

3. Reduce Data to Information as Soon as Possible - Extract information from data and discard useless data at the earliest practical point in the system.

4. Standard Interfaces and Protocols

5. Build to Integrate/Test/Operate - The system should be transparent between the sensor and the user.

6. Fail Soft/Modular Redundancy - To achieve high availability.

Some of the NEEDS activities that have potential application to the SASP end-to-end data system include the Modular Data Transport System, the Information Adaptive System, the Data Base Management System, the Archival Mass Memory, the Massively Parallel Processor, and Synthetic Aperture Radar (SAR) processor development. Details of these activities can be found in NEEDS program documents.

8.1.6 Overall TDRSS Loading

Early studies at MSFC and GSFC have shown that the TDRSS will be overloaded in the late 1980's. The result of this overloading would be that schedule conflicts will arise and data will be lost for lower priority spacecraft. This conclusion, of course, is dependent on the mission scenario used. The SASP follow-on end-to-end flow study will examine this loading in more detail using the Data System Dynamic Simulator (DSDS) at MSFC.

The studies have shown, however, the effect of inefficient use of TDRSS channels. The channel usage is typically inefficient in the sense that TDRSS channels are used at data rates much lower than their capacity, thus greatly increasing the TDRSS timeline that is used for a given amount of data transmitted.

8.1.7 Mission Operations Concepts

Figure 8.1.7-1 shows the reporting relationships envisioned in the overall SASP mission management concept. This chart defines the data flow requirements that result from the mission operations concept. Data requirements in this category are primarily for "real-time" data.

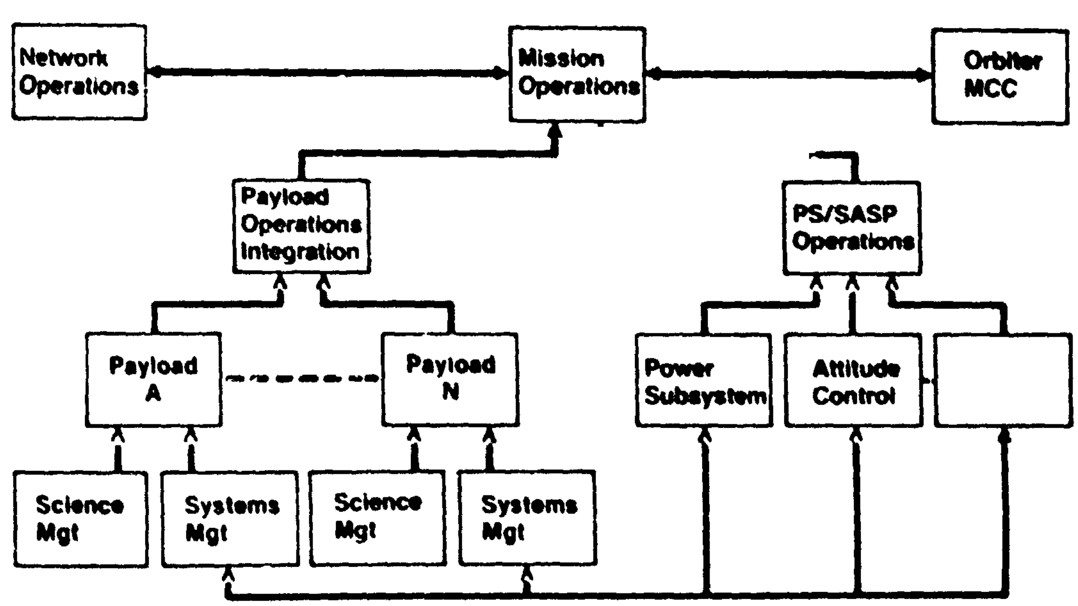
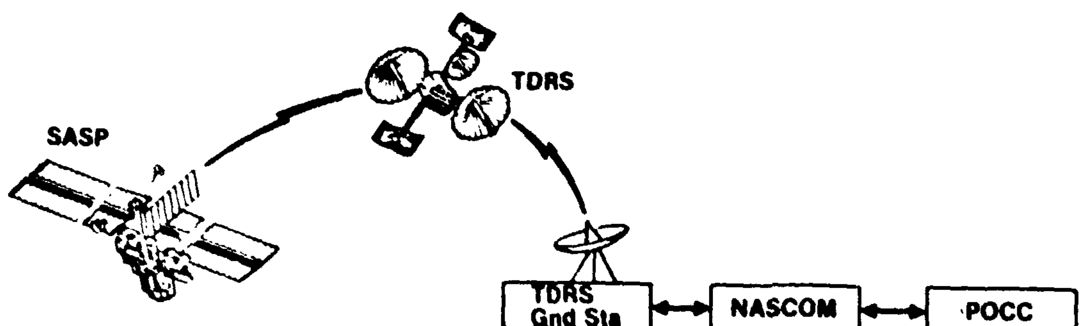


Figure 8.1.7-1 SASP Mission Operations Management

8.1.8 Response Time Considerations

Many payload definitions include a requirement for real-time interactive control, including real-time downlink data and command capability. Because TDRSS forward links are less plentiful than return links, it is unlikely that SASP will have a full-time dedicated forward (command) link.

Response time for interactive control may be evaluated for two cases. One is for the case where the real-time interactive control takes place in a relatively short, pre-planned time so that a TDRSS forward link can be scheduled and dedicated to SASP for the time needed. The second case is where an experimenter needs to respond to an unanticipated event in the experiment data by sending a command to the payload. The TDRSS capability to meet this situation, where a command link must be scheduled after the downlink data event is seen, is summarized in Figure 8.1.8-1. Note that the response time will probably exceed five minutes. The adequecy of this response time for typical payloads was not investigated.



Response Time — Delay Between Payload Event and Transmission to Payload of Command in Response to That Event

Planning Factors

TDRSS Emergency Service Response Time	— 5 Minutes
TDRSS MA Acquisition Time	— 15 Seconds
POCC Operator Response Time	— Variant
Propagation Delays and Processing Times	— <<15 Seconds

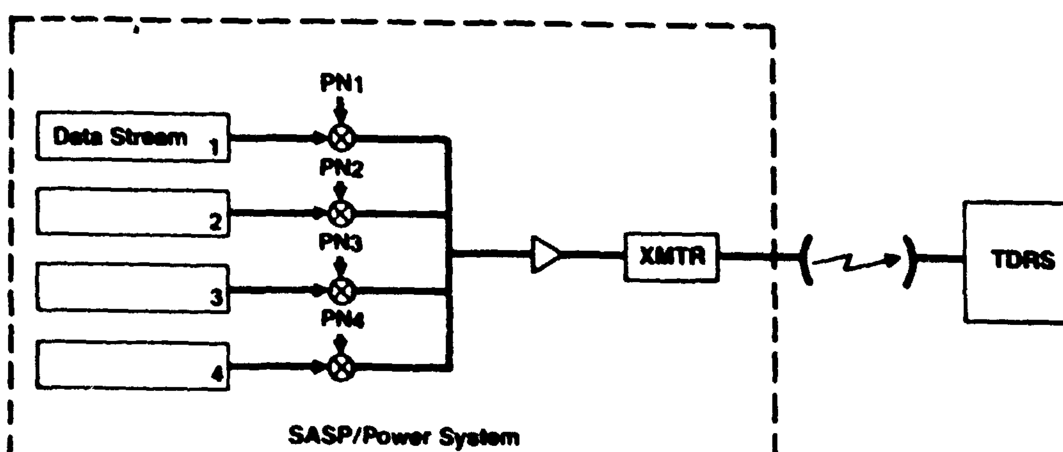
Adequacy TBD

Figure 8.1.8-1 Interactive Control - Response Time

8.1.9 Real-Time Downlink

A number of payloads have defined a requirement for real-time downlink data at a rate of 50 Kbps for purposes of implementing interactive control. TDRSS provides multiple access channels, each with a nominal 50 Kbps capacity, which are intended for dedicated use by a spacecraft. However, if a SASP payload group included two or more payloads with such a 50 Kbps real-time requirement, a single TDRSS MA channel would not be sufficient.

Figure 8.1.9-1 defines a possible solution to this requirement that involves the use of more than one MA channel to meet data rate requirements in excess of 50 Kbps. The MA channels in TDRSS all operate at the same carrier frequency and are separated by PN coding and, in the free-flying case, by antenna gain differences. For the proposed concept, channel separation would, of course, depend on PN coding. This concept requires further analysis to determine the effect on 25 kW Power System EIRP requirements, the interference that might result to other MA users, and the total data rate that would be achievable.



- Goal: Provide "Continuous" Data at Rates > 50 KBPS
- Each Data Stream is 50 KBPS or Less
- Each Data Stream has Different PN Code
- Technical Issues - (1) Mutual Interference
  (2) Power System EIRP
- Preliminary Indications Are That Up To 4 Data Streams of 50 KBPS Each Can Be Simultaneously Transmitted

Figure 8.1.9-1 Approach to TDRSS MA Usage >50 Kbps

8.1.10 SASP Compared to Free-Flyers

As discussed earlier, TDRSS loading depends strongly on the downlink data rates of the using spacecraft. A method for alleviating the TDRSS loading and potential schedule conflicts is to provide high rate recorders on the using spacecraft so that data can be stored and then dumped at a high rate. This can be done more economically on a SASP, where the recorder capability can be provided as a central resource, than on free-flyers. In addition, SASP has the advantage that a data dump can include data from several payloads in a single dump, thereby minimizing the TDRSS acquisition time compared to the free-flyer case. Figure 8.1.10-1 shows an example comparison of the TDRSS SA time required for three free-flyers versus the SA time required for the same three payloads on SASP. For this particular case and the dump rate assumptions shown, SASP has a 5:1 advantage over the free-flyers in SA time required to dump the same amount of data.

- **Three Payloads as Free-Flyers**

	Data Rate	Bits/Orbit	Assumed Dump Rate	SA Time Per Orbit
HE-1	10^5 bps cont.	5.4×10^8	10^6 bps	11 min
AST-4	10^6 bps cont.	5.4×10^9	10^7 bps	11 min
MEA	50 bps	1.3×10^7	10^6 bps	2m 14s
			Total	24m 14s

- **Same Three Payloads on SASP (with 32 mbps Spacelab Recorder)**

Bits/Orbit	Dump Rate	SA Time Per Orbit
6×10^9	32×10^6 bps	5m 6s

- **For This Particular Group of Payloads, SASP Reduces SA Channel Usage and Charges by a Factor of 5 or More and Significantly Enhances TDRSS Scheduling Opportunities. This Advantage is Made Possible by the SASP Recording Capability and by the Inherent Elimination of Separate TDRSS Acquisition Sequences**

Figure 8.1.10-1 TDRSS Utilization - Example of F/F vs SASP

8.2 CONTAMINATION

8.2.1 Overview

The objectives of this special emphasis task were to (1) define the nature of the problem, (2) determine the status of problem understanding, and (3) identify operations which can cause problems and identify possible countermeasures.

The task effort concentrated on contamination aspects of outgassing, early desorption, and particulates. Both outgassing and early desorption result in molecular quantities along the line-of-sight (Number Column Density Limit) or that is reflected back towards the sensors where it may adhere to the sensitive surfaces (Return Flux limit). The outgassing of concern is a long-term weight loss from non-metallic materials while early desorption is a short-term weight loss due to non-metallic materials. Consequently, early desorption rates fall off and sensor protection may be necessary only for short time periods.

Particulate contamination will be generated as a consequence of material wear, micrometeoroid impact, or embrittlement and flaking of protective materials when exposed to space radiation and thermal cycling. Experience with both manned and unmanned missions has shown particulate generation and presence in sensor data. To date, particulate generation has not been computer modeled and in general there have been work arounds devised to avoid particulate showers which have occurred.

8.2.2 Applicable Contamination Documents and Requirements

Initial payload contamination requirements are found in Reference 8.2-1. This reference requires that all payloads have cleanable surfaces, that cargo effluents shall not result in payload cross contamination or jeopardize Orbiter system performance, and that cargo fluids vented overboard shall not

jeopardize mission objectives. In addition, Reference 8.2-2 is imposed on all payloads and covers vacuum stability requirements for non-metallic payload material. The latter general specification limits material maximum Total Mass Loss (TML) to one percent with a maximum Volatile Condensible Material (VCM) content of 0.1 percent during specified testing. Since materials waivers can be obtained on this requirement, payload control of non-metallic materials is not absolute.

Shuttle Orbiter contamination requirements start with Reference 9.2-3. This reference imposes a requirement that the internal surfaces of the payload bay envelope shall be cleaned to a "visibly clean" level before payload loading. Requirements are also established for payload bay cleaning, control of work activities, and supply of class 5000 air. The reference also states an Orbiter design and operational goal that---" venting of gases and liquids from the Orbiter will be limited for sensitive payloads to control in an instrument field of view particles of 5 microns in size to one event per orbit, to control induced water vapor column density to 10^{12} molecules/cm^2 or less, to control return flux to 10^{12} molecules/cm^2/sec, to control continuous emissions or scattering not to exceed 20th magnitude/sec^2 in the UV range, and to control to 1% the absorption of UV, Visible, and IR radiation by condensables on optical surfaces. Materials which can contaminate either the payload, payload bay or Orbiter window by outgassing when exposed to the vacuum environment shall be selected for low outgassing characteristics as defined in Paragraph 3.6.2.1. "...The reference paragraph invokes Reference 8.2-4 which in turn imposes Reference 9.2-2 for non-metallic materials.

8.2.3 Defined Payload Requirements

The environmental concerns of OSS and OSTA payloads (References 2-2 and 2-5) were reviewed and it is apparent that only a few payloads have established definitive limitations. (E.g., 6 of 74 payloads.) Forty-three percent of all payloads indicated concern over contamination while the remainder indicate their concern is TBD. Specified limits are as follows:

TECHNOLOGY	AREA OF CONCERN	LIMIT
ASTRONOMY	RETURN FLUX	$\leq$ 2 x 10" MOLECULES/CM^2/SEC/STR
	COLUMN DENSITY	$\leq 10^{12}$ MOLECULES/CM^2
	PARTICLES	$\leq$ 1 PARTICLE $\geq 2\mu$/FOV
LIFE SCIENCES	G LEVELS	$\leq 10^{-3}$ G'S

It is worth noting that section 10.6 of Reference 8.2-1 predicts both column density and return flux for Orbiter leakage, flash evaporator operation, and for both Vernier and main RCS operation. Predicted Column Density ranges from 1.9×10^{12} to 3.4×10^{16} molecules/cm^2 while Return Flux ranges from 1.7×10^{11} to 2.6×10^{15} molecules/cm^2/sec. From these data, it is safe to assume that contamination sensitive payloads should be shutdown and sensitive equipment covered during the time the Orbiter is present.

Further, the leakage contamination from the Orbiter suggests that pressurized modules probably should not be combined with sensitive payloads. The same logic indicates sensitive payloads should not be considered for Sortie mission operations.

8.2.4 Payload/Pallet Contamination Effluent

Spacelab flight documents were reviewed to determine attendant contamination effluents. This was done assuming these data would be representative of

the payload community. The results reported in References 8.2-5 through 8.2-7 were determined by the same computer program that developed the predicted Orbiter environment cited above. The results are shown in Figure 8.2.4-1 which also indicates the percentage of time the experiments will be operated. As can be seen, a number of payloads have high column density predictions and TBD return flux predictions. Thus, within the payload community there will be reason for payload scheduling to eliminate inter-payload interferences.

TECHNOLOGY AREA	ELEMENT	COLUMN DENSITY (MOLECULES/CM^2)	PERCENTAGE TIME OPERATED	
• PLASMA PHYSICS	A	3.7×10^{14}	13	
PLASMA	N_2	2.0×10^{18}	13	
	H_2	1.3×10^{16}	49	
• ATMOSPHERIC PHYSICS	N_2	3.4×10^{14}	28	
• HI ENERGY PHYSICS	X_e	5.4×10^{11}	100	
	H_e	1.1×10^{13}	100	
	CO_2	5.4×10^{11}	100	
	X_e	1.4×10^{13}	~1	
	CH_4	3.7×10^{12}	~1	
• IR ASTRONOMY	H_e	1.6×10^{13}	100	
• TECHNOLOGY	H_e	2.6×10^{13}	100	
• FLUID AND AEROSOL DYNAMICS	N_2	4.6×10^{14}	TBD	30
	O_2	1.1×10^{14}	TBD	
	H_e	1.1×10^{17}	TBD	

*NOMINAL LIMIT - OSS PAYLOADS $\lesssim 10^{12}$ MOL./CM^2

Figure 8.2.4-1 Contamination Effluents* Spacelab Experiments (SL 1, 2. 3)

Additional contamination data were obtained from Reference 9.2-8 which provides expected effluent levels for Spacelab and pallet configurations within the Orbiter payload bay. These data represent a worst case calculation for the platform configuration. Figure 8.2.4-2 provides these projections which exclude all Orbiter or payload effects. The predicted levels are due entirely to non-metallic materials on the lab module and pallet plus lab module atmospheric leakage. No effects of the Spacelab vent system are included. Several interesting observations can be made from these data.

SOURCE	PALLETS ONLY	LAB AND PALLETS
• COLUMN DENSITY (MOL/CM^2)		
– OUTGASSING	1.3×10^8 (AVG)	1.9×10^9 TO 1.1×10^{10} (AVG)
– EARLY DESORPTION	2×10^{11} (AVG)	2.1×10^{12} TO 4.5×10^{12} (AVG)
• RETURN FLUX (2π SR – $MOL/CM^2/SEC$)		
OUTGASSING	1.4×10^{10}	1.6×10^{11} TO 8.7×10^{11}
EARLY DESORPTION	2.4×10^{13}	2.4×10^{14} TO 5.0×10^{14}

*ASSUMES ORBITER PAYLOAD BAY, NO ORBITER AND NO EXPERIMENT CONTRIBUTION

Figure 8.2.4-2 Pallets Only vs Spacelab and Pallets*

First, the long-term outgassing effects result in below payload limit conditions once the short term early desorption dies down. Second, the contaminant levels are an order of magnitude higher due to atmospheric leakage from the lab module. The upper range for return flux values is above the Orbiter design and operational goal even though no payload equipment effects have been included. Again, there is indication that pressurized modules should not be scheduled together with sensitive payloads.

The remarkable difference between early desorption and steady state outgassing (three orders of magnitude) further emphasizes the need to cover sensitive payload elements whenever the Orbiter is present or whenever new payload sets are delivered to the Platform.

8.2.5 Other Potential Contamination Sources

Contamination analysis is a developing art based on computer modeling of all the system elements to obtain lines of sight between sensors and sources. Further, the analysis requires accurate knowledge of materials selected, material quantities, and material outgassing test results. In the case of the combined Power System, platform configuration, and payloads most of the

necessary information is lacking. Both requirements and possible contamination effluent levels have been presented in the preceding paragraphs of this task reporting; however, definitive design details are lacking.

A quick review of the system elements permits a top level listing of areas needing further analysis, as follows:

- Solar array including deployment system
- Radiators and radiator fluids
- Reboost module
- Control moment gyros
- Batteries
- Mechanisms for pointing, deploying, and rotating
- Lubricants
- Micro-meteoroid impacts on metals, composites, thermal costings, paints, etc.
- Maintenance and repair operations
- EVA Servicing operations/effluents
- RMS placement/removal of pallets/payloads
- Cryogenic and purge gas operation and replacement
- Orbiter/platform telescoping boom interface

While this top level checklist is impressive, it is appropriate to recognize that equivalent problems exist also for free flying payload systems where separations between source and sensor is a lesser design option.

A review of the Power System solar array was made since this single systems element has been under development for the Solar Electric Propulsion program. It was assumed that the array represented the most mature design item that could be identified. Table 8.2.5-1 provides a breakdown of potential outgassing

- **OUTGASSING**
  - ADHESIVE ON SOLAR CELL COVERS – $\boxed{\text{DC93-500}}$
  - ADHESIVE BETWEEN KAPTON SHEETS – HIGH-TEMPERATURE POLYESTER
  - ADHESIVE ON FIBERGLASS CLOTH – TFE TEFLON HINGE STRIPS BONDED TO KAPTON PANELS – HIGH-TEMPERATURE POLYESTER
  - SOLAR ARRAY VERTICAL AND HORIZONTAL PADDING – $\boxed{\text{RTV 511}}$ OR 577 SILICONE
  - LUBRICANTS ON ARRAY GIMBAL AND DEPLOYMENT CANISTERS
  - S GLASS/POLYIMIDE LONGERONS AND BATTENS
- **PARTICULATES**
  - DRY LUBE USED ON SOLAR ARRAY TENSIONING SYSTEM (DRUMS, REELS, SHAFTS)
  - FIBERGLASS CLOTH – S GLASS EPOXY HINGE PINS
  - DACRON BRAIDED CORD/PANEL EYELETS
  - MATERIAL WEAR DURING EXTENTION – RETRACTION OF COILED MAST (ALUMINUM DEPLOYMENT NUT, ALUMINUM ROLLER LUGS, ROTATABLE NUT, ROLLER GUIDE, DRIVE MOTOR, STEEL BEARINGS IN ALUMINUM TURNTABLE, S.S. KAYDON BEARINGS, AND VESPEL PINION GEARS)
  - THERMAL COATINGS ON LONGERONS/BATTENS
  - MICROMETEOROID IMPACT ON SOLAR CELL COVERS, LONGERONS, ETC.

BASED ON LMSC-D 492693, MID-TERM REPORT, 18 JANUARY 1977

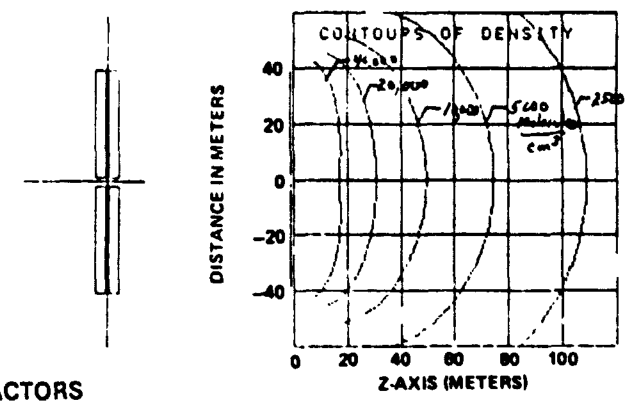
$\boxed{}$ = Acceptable Material Test Results

Table 8.2.5-1 Potential Contamination Sources PM Array

materials and potential particulate sources. With the available design definition it was possible to identify only two materials for which there are acceptable materials; the design definition was insufficient to make further determinations.

In light of the limited SEPS system material definition, a preliminary analysis was conducted to determine what reasonable contribution to column density might come from the arrays. Consequently, material test data (outgassing) were examined and an initial outgassing rate of 10^{10} molecules/cm^2-sec was selected as portraying a design believed to be representative of the SEPS array. Using this data, analyses were made and reported at the midterm (Reference 8.2-9) reporting. Figure 8.2.5-1 summarizes this analysis and itemizes the physical factors involved. Column density along the Z-axis was calculated for a range of atmospheric densities and for a collision cross section a factor of 10 higher than normal. It can be seen that column densities are $< 2 \times 10^8$ molucules/cm^2, nearly four orders of magnitude below the minimum sensor detection level and limit.

SOLAR PANEL GEOMETRY AND CLOUD SHAPE



PHYSICAL FACTORS

- AREA – FLAT – 5.9×10^{6} cm^2
- RATE – 10^{10} MOLECULES/(cm^2 SECOND)
- COLLISION X SECTION – 7.3×10^{-16} cm^2 ATOMIC OXYGEN VERSUS WATER
- AMBIENT DENSITY – 40:1 RANGE $1.6 \times 10^{+7}$ TO 6.6×10^{8} MOLECULES/cm^3
- COSINE OUTGASSING PATTERN
- MEAN FREE PATH = f (DENSITY AND CROSS SECTION)

COMPUTATION METHOD

- 0.1 PERCENT CALCULATIONS FOR 1.0 PERCENT ACCURACY
- COORDINATE SYSTEM – PANEL CENTERED
- VARY PANEL ZONE AREA FOR REQUIRED ACCURACY

RESULTS

CONFIGURATION	AMBIENT (MOLECULES/cm^3)	Z-AXIS COLUMN DENSITY (MOLECULES/cm^2)
LOW AMBIENT –	1.6×10^{7}	1.601×10^{8}
MID AMBIENT –	7.6×10^{7}	1.595×10^{8}
HIGH AMBIENT	6.6×10^{8}	1.555×10^{8}
ARBITRARY AMBIENT	6.6×10^{9}	1.31[illegible]
ARBITRARY CROSS SECTION X 10, 6.6×10^{8}/cm^3		1.3[illegible]9 $\times 10^{8}$

Figure 8.2.5-1 Column Density - Analysis

A second analysis was made comparing the uniform outgassing model assumed in the above analysis to a structured solar array outgassing characteristic which should simulate the SEPS design. The resultant density contours were compared to that shown in Figure 8.2.5-1 and the structural outgassing contours are lower; thus, the predicted column densities should be conservative. It should be noted that the ambient atmosphere's composition is primarily atomic oxygen which has a near zero InfraRed signature and need not be added to the H_2O density given along the Z-axis.

Similar calculations should be made to determine Return Flux predictions for similar variations in atmospheric density and collision cross sections.

8.2.6 Recommendations

Recommendations are summarized on Table 8.2.6-1. Continued material development and testing will be needed to assess the range of materials which will be used in systems and payloads to be developed.

- C[illegible]NUE MATERIAL DEVELOPMENT AND TESTING
- EXPAND COMPUTER MODELING TO INCLUDE PS AND SASP
- OBTAIN ON ORBIT CONTAMINATION MONITORING DATA WITH INDUCED ENVIRONMENT CONTAMINATION MONITOR (IECM)
- CORRELATE IECM RESULTS WITH TEST DATA AND MODELING (LDEF)
- CONSIDER IECM WITH OTHER PAYLOAD FLIGHTS
- UPDATE COMPUTER MODELS
- AVOID COMANIFESTING CONTAMINATION SENSITIVE PAYLOADS WITH INSENSITIVE PAYLOAD OF HIGH CONTAMINATION POTENTIAL
- PROVIDE REUSABLE SENSOR SHROUDS/COVERS AND PLAN COVERUP DURING ORBITER PRESENCE, MAINTENANCE OPERATIONS, PAYLOAD CHANGEOUTS, SUBSATELLITE DEPLOYMENT/RETRIEVAL, EVA ACTIVITIES, AND FOR EARLY DESORPTION

Table 8.2.6-1 Recommendations on Contamination

In time, expansion of the current computer model to encompass the Power System, candidate platforms, and representative payloads should be accomplished. Selection of the payloads may be subject to much debate; however, it seems appropriate to identify extremes. One payload should be representative of a "pig-pen" system while the other should represent a payload with very rigid cleanliness requirements. It is possible that an IR telescope such as the SIRTF might be appropriate since it will have to contend with effluents from cryogenic helium.

Every effort should be made to obtain actual flight data results using the NASA-MSFC developed Induced Environment Contamination Monitor (IECM) which

will measure both gaseous and particulate matter. Planned use of this instrument should be stressed and the resultant data should be used to correlate IECM results with both test data and the computer model. Scheduled use of the instrument on the LDEF should also provide useful data about contamination from the Orbiter during launch, deployment, and ultimately with LDEF rendezvous and retrieval. These data should be valuable in understanding and controlling contamination. Updating of the computer model and assumptions should result.

From a practical point of view, highly sensitive payloads should not be flown with those which will have high effluent rates. This type of payload scheduling may have direct impact on platform design and usage; however, additional payload data will be necessary before any effects can be addressed.

Reusable payload sensor covers will be a practical necessity when the full range of on orbit operations are considered. Table 8.2.6-1 itemizes a number of these operations and periodic coverup of sensitive equipment will be required at intervals associated with Orbiter revisit. It also is worth noting that proposed free flying payloads will present a similar problem regards contamination. Further, these subsatellites also present a unique collision risk which remains to be evaluated.

8.3 ROTATING JOINT

8.3.1 Introduction

This section covers all the rotational mechanisms required to satisfy the pointing, loading, and servicing of the SASP. The mechanisms to be covered are as follows:

- 1st Order SASP $\pm$Y and +X ports

  $\pm$90° rotational joint
- 2nd Order SASP $\pm$Y arms

  $\pm$180° rotational joint
- 2nd Order SASP growth trail arm 360° rotational joint
- 2nd Order SASP telescoping boom rotational joints

8.3.2 Rotating Joints

The initial study of the SASP indicated a need for a 360° rotational joint for the two cross arms and the trail arm to satisfy the payload viewing requirements. As the study proceeded and the new flight scenario was modified and the requirement changed to where a $\pm$180° rotational feature was required for the cross arms and a 360° rotational for the trail arm, the thermal study also indicated that there would be no need for a fluid transfer across the 360° trail arm, only data and power.

The final concept for the 1st and 2nd Order SASP are as follows:

- The 1st order's +Y and +Z payload support truss requires $\pm$90° rotation and data, power, and coolant to be flexed across the rotational joint.
- The 2nd order $\pm$Y cross has $\pm$180° rotation and requires the data, power and coolant to be flexed across the joint. The +X port trail arm rotates 360° and requires data and power to be transferred by means of roll rings. There are no requirements for transfer of fluid across this 360° rotational joint.

8.3.2.1 Requirements

360° Trail Arm Rotational Joint Requirements

- Travel: 360° Continuous and Infinite Pointing Position
- Rate: 0 to 0.5°/Sec

- Torque: 200 ft-lb Stall
- Backlash: Zero
- Pointing Accuracy: 12 Arc Min or Less
- Power Transfer: 25 kW at 30 and 120 VDC
- Data Transfer: 40 Circuits at 3 MB/Sec
- No Coolant Transfer Across Joint
- Envelope: 1.0 m Diameter x 1 m Long
- Drive Power: 50 Watts

1st Order Platform Rotational Joints Requirements +Y and +X Arms

- Travel: Three position 0° $\pm$ 90°
- Rate: 0 to .5/Sec
- Torque: 200 Ft-Lb Stall
- Backlash: Zero
- Pointing Accuracy: 12 Arm Min or Less
- Power Transfer: 6 kW at 30 and 120 VDC
- Data Transfer: Flexed Across Joint
- Coolant Transfer: Flexed and Swiveled
- Drive Power: 50 Watts

2nd Order Platform Cross Arm Rotational Joint Requirements

- Travel: Infinite Position Between $\pm$180°
- Rate: 0 to .5/Sec
- Torque: 200 F-Lb Stall
- Backlash: Zero
- Pointing Accuracy: 12 Arc Min or Less
- Power Transfer: 25 kW at 30 and 120 VDC
- Data Transfer: Flexed Across Joint
- Coolant Transfer: Flexed and Swiveled
- Drive Power: 50 Watts

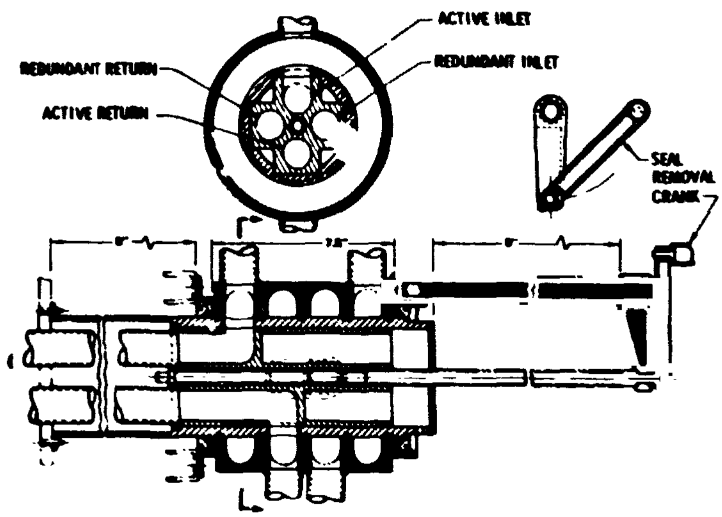


Figure 8.3.2-3 Rotary Fluid Coupling
Operating Position

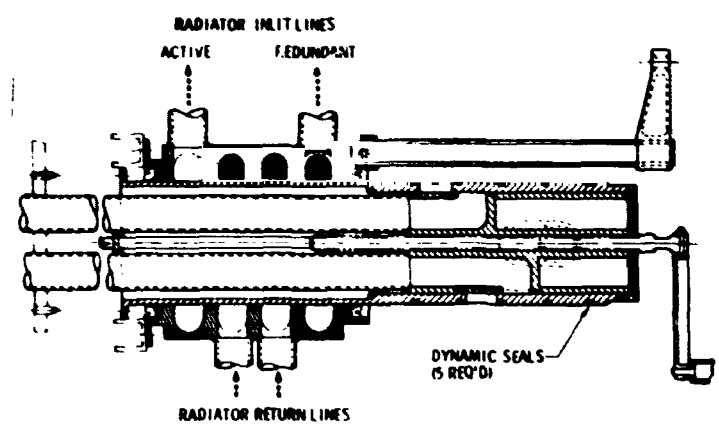


Figure 8.3.2-4 Rotary Fluid Coupling Positioned for
Seal Replacement

Figure 8.3.2-1 illustrates the initial concept for the 360° rotary joint which was required in the two cross arms and on the trail arm. Figure 8.3.2-2 shows the power and data transfer details. Figures 8.3.2-3 and 8.3.2-4 illustrate the fluid transfer concept and the method to replace the seals in orbit without spillage. This repair method was to incidate that it is possible to repair in orbit. The requirement now indicates that there is no need for transferring fluid across the 360° joint unless the trail arm radiators cannot dissipate the heat generated. Figure 8.3.2-5 schematically illustrates the latest concept for the 360° joint which is capable of transmitting data and power. The design can be made to transfer fluid if such a requirement did exist.

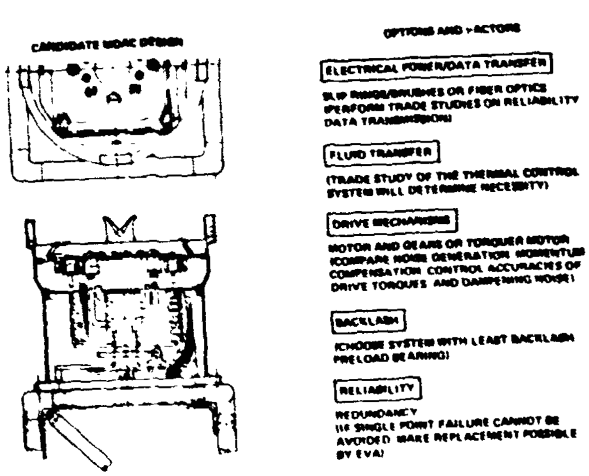


Figure 8.3.2-1 Rotating Joint Concept and Considerations

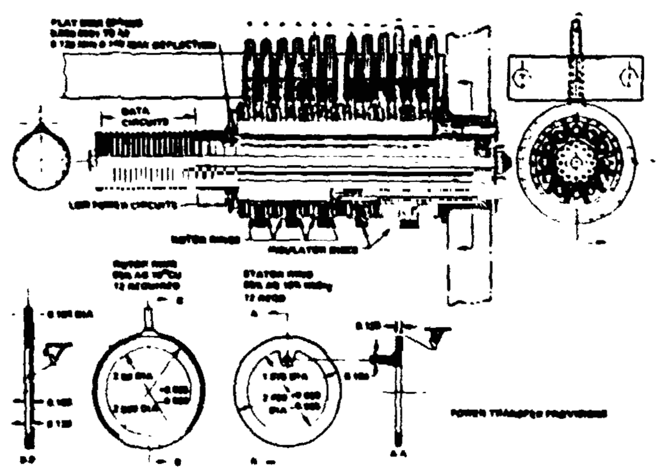


Figure 8.3.2-2 Power Transfer Provisions

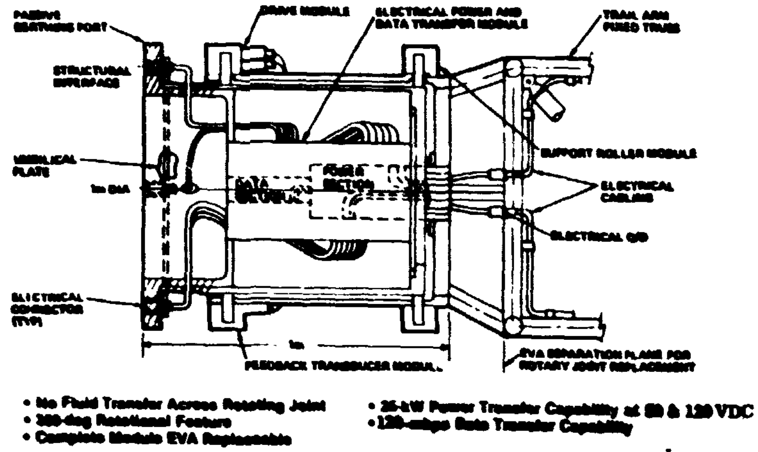


Figure 8.3.2-5 Trail Arm 360-Deg Rotational Joint

The rotating joint provides such features as 360° rotation, passive umbilical and berthing port infinite indexing position, quick change out of the drive motor, and complete rotary joint in case of electrical transfer failure.

The passive berthing port will have provisions for coolant Q/D but is not required for this configuration. The unit only transmits power and data across joints by means of roll rings. It is capable of transmitting 25 kW of power and 120 Mbps of data.

Figure 8.3.2-6 illustrates another concept for a 360° rotary joint. This method utilizes rollers in line with the main longeron to transfer the tension and compression loads across the rotary joint without inducing bending. The data and power and fluid transfer system are located in the center. The rotational drive mechanisms are mounted externally for ease of replacement.

The three rollers which carry the axial and radial loads are shown in Figure 8.3.2-7. A thin butyl tire is molded on the outer face of a standard sealed bearing to form the roller.

The 1st and 2nd order cross arm and the 1st order trail arms concept of the rotary joint are similar (see Figures 8.3.2-8 and 8.3.2-10). The only differences are the $\pm 90°$ rotation for the 1st order and $\pm 180°$ rotation for the 2nd order cross arms and the direction of rotation. The load transfer system is similar to the details shown in Figures 8.3.2-6 and 8.3.2-7 except the drive mechanism is located near the center and the data and power cables are flexed across the joint, the fluid line is swiveled across the joint. This concept is designed for ease of EVA drive actuator replacement.

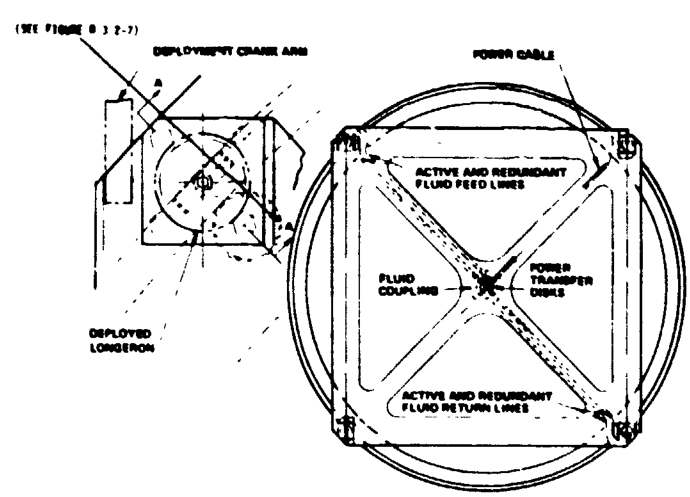


Figure 8.3.2-6 Rotary Joint

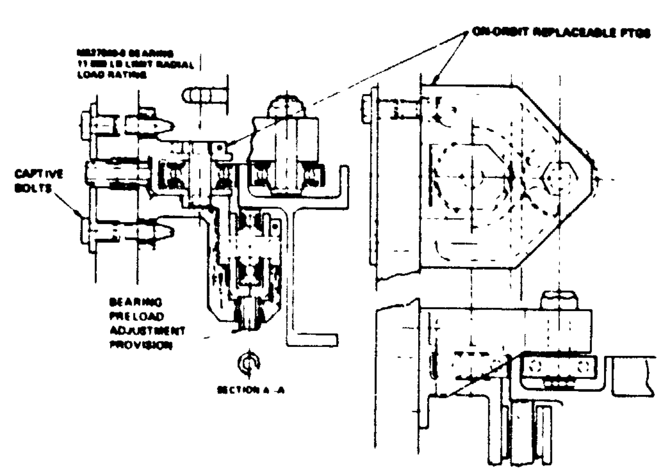


Figure 8.3.2-7 Rotary Joint Details

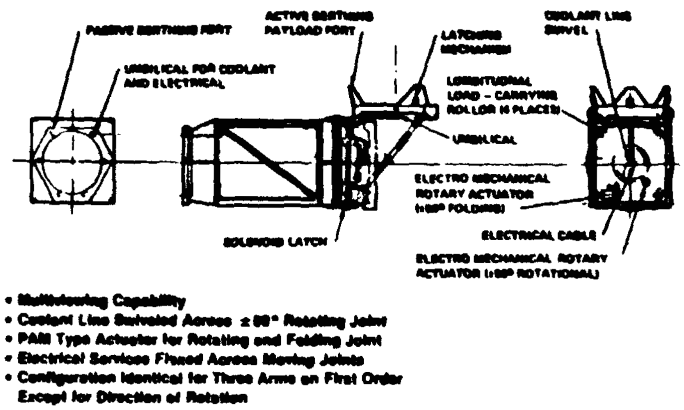


Figure 8.3.2-8 First-Order Platform Payload Berthing Structure and Mechanism

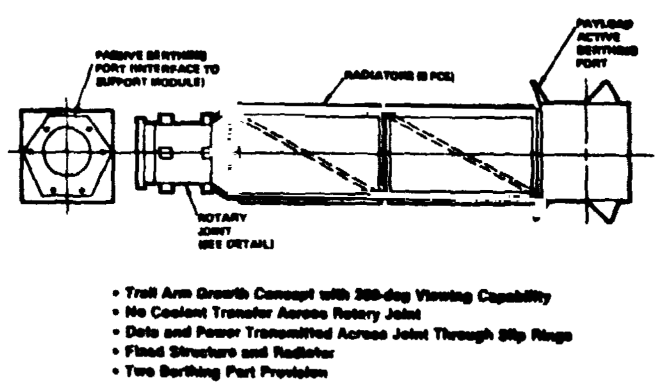


Figure 8.3.2-9 Trail Arm Fixed Truss with 360-Deg Rotary Joint

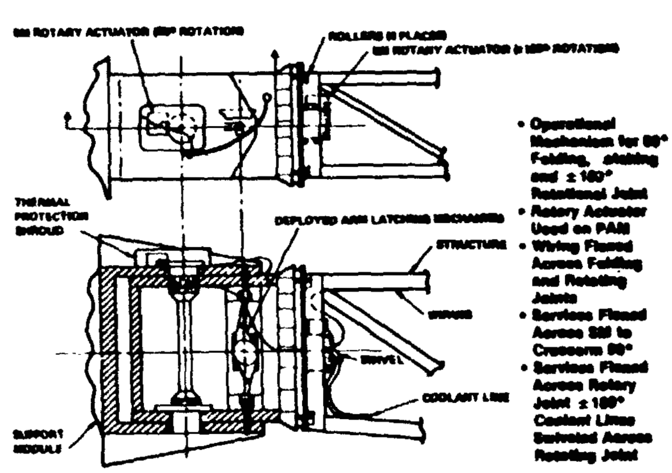


Figure 8.3.2-10 Second-Order Platform Arm Folding Joint Mechanism

Trade Studies (for 360° Rotational Joint)

Trade studies were accomplished on methods for transferring power, data, (e.g., slip ring and brushes, rotary transformer, fiber optics, etc.) and fluids (if proposed thermal control systems dictate this requirement).

360° Rotating Adapter

OPTIONAL APPROACHES	COMMENTS
• Electrical Power and Data Transfer • Slip Rings and Brushes • Fiber Optics	• Perform Trade Studies on Reliability, Data Transmission
• Fluid Transfer	• Trade Study of The Thermal Control System will Determine Necessity
• Drive Mechanisms	
• Motor and Gears	• Compare Noise Generation
• Torquer Motor	• Momentum Compensation • Control Accuracies of Drive Torques • Dampening Noise
• Backlash	• Choose System with Least Backlash • Preload Bearing
• Reliability	
• Redundancy	• If Single Point Failure Cannot be Avoided, Make Replacement Possible by EVA.

360° Rotational Adapter (Continued)

OPTIONAL APPROACHES	MAJOR CHALLENGES
• Slip Ring and Brushes	• Determine Envelope Size for Minimum Length Unit • Data Transmission Capability
• Noise Generation	• Determine Method to Dampen if Required
• Failure Repair	• Make Provision for Easy Changeout by EVA
• Fluid Leakage	• Design System Redundant and Zero Leakage Phase D

360° Rotating Joint Conclusions

The trade study on this rotary joint indicates the following order of preference in selection of the components and subsystems. (See Table 8.3.2-1.)

ITEM	CHOICES TO BE CONSIDERED IN ORDER OF PREFERENCE	REMARKS
POWER TRANSFER	• ROLL RINGS • DISK SLIP RING/BRUSH • RADIAL SLIP RING/BRUSH • FLAT SLIP RING/BRUSH	ROLL RINGS HAVE POTENTIAL ADVANTAGE OF LOW FRICTION, LOW NOISE COMPACT DESIGN AND LOW CONTACT RESISTANCE
DRIVE MOTOR	• GEARHEAD D.C. BRUSHLESS • GEARHEAD STEPPER • GEARHEAD D.C. • DIRECT DRIVE D.C. TORQUER • AC MOTOR	BRUSHLESS D.C. MOTOR ELIMINATES BRUSH WEAR PROBLEM DIRECT DRIVE TORQUERS LARGE HEAVY AND REQUIRE MUCH POWER.
DRIVE TRAIN	• FRICTION/PLANETARY • SPUR GEAR • WORM GEAR • HARMONIC DRIVE • DIRECT TORQUER	FRICTION DRIVE PROVIDES SMOOTH OPERATION WITH NO BACKLASH
FLUID TRANSFER	* • SPOOL AND SLEEVE SWIVEL	NEEDS FURTHER INVESTIGATION

*IF REQUIRED

Table 8.3.2-1 Rotating Joint Design Options

8.3.3 Telescoping Boom Rotating Joint

During the third quarter phase of the study a requirement was generated to have a structure between the Orbiter and the 2nd order SASP to aid in loading and unloading the payloads. It was noted that the Orbiter has fuel only to dock once to the SASP or Power System during a visit. This necessitates designing a piece of equipment which can be part of the SASP and folded out of the way when not in use. Figure 8.3.3-1 illustrates a telescoping boom designed to the following requirements:

Berthing Boom Requirements

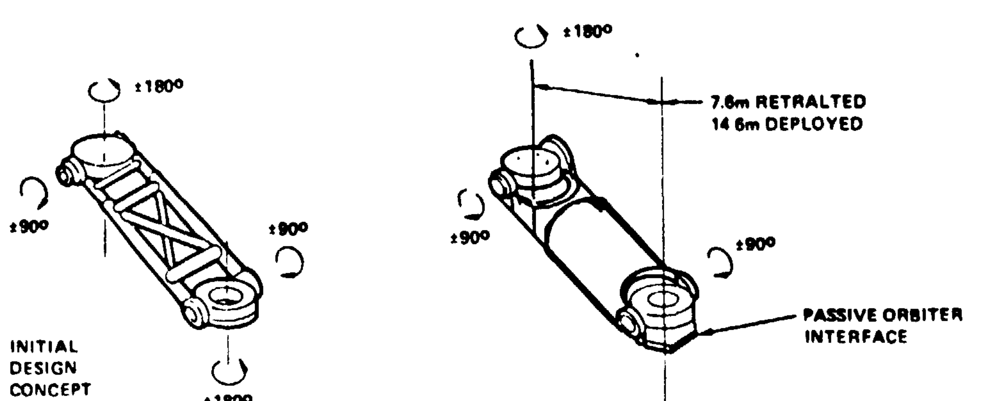
- Retracted Center to Center Length 7.6m
- Telescoped Length 14.6m
- Design Limit Load 125,000 ft#
- Stiffness to be Equal to Platform Stiffness
- Rotational Features
  - Platform End and Orbiter End ±180° Pitch and Yaw

- Passive Berthing Port on Orbiter End
- Platform End may be Permanently Attached to Support Module
- Boom Stowed Under Support Module and Extension for Launch and Deployed During Servicing and Sortie Flight Modes

Work Accomplished

MDAC performed analysis of a rotating joint (gimbals) per an IRAD study. The preliminary results indicated the following conclusions:

- Components are State of the Art
- Roll Rings Selected for Power and Data Transfer
- Fluid Seal Leakage and Wear, Limits Life or Assembly
- Seal Replacement on Orbit Considered Impractical
- Roller Type Suspension and Friction Drive Selected because of Modular Design and Smooth Operation for 360° Rotational Joint
- Brushless DC Drive Motors Selected for Low Weight and Long Life



- Present Design Selected Bsed on Greater Stiffness Capability in the Constrained Launch Envelope
- Features:
  - Electrical Cabling Flexed Across Rotating Joints
  - Coolant and Cabling Looped Stowed Across Telescoping Section
  - Jack Screw for Extension Feature
  - Indexed to Preclude Rotational in Telescoping Section

- Rotational Features by Electromechanical Gear Train Servoactuator
- Infinite Position Stop Provision
- Infinite Extension Stop Position End to End
- Coolant Across Joints with Swivel

Figure 8.3.3-1 Telescoping Boom for Orbiter Berthing and Loading Aid

Section 9
PROGRAMMATICS, COSTS AND SCHEDULES
(Task 9)

The results of effort in this task are reported in Volume III, same title.

Section 10
CONCLUSIONS AND RECOMMENDATIONS

A summarization of the conclusions and recommendations of the study are presented in this last section of the report.

10.1 OVERALL CONCLUSIONS

- The Platform configuration selected can effectively support from 80-85% of the NASA/OSS and OSTA payloads planned for the mid-to-late eighties from a performance standpoint (in-house NASA programmatics analyses indicated considerable cost benefits for payloads with the Platform mode).

- The modularity, shape, and size of the recommended Platform concept offers:
  - a low-investment, elemental module option to demonstrate basic system performance early.
  - flexibility for conservative growth as needs or funds permit.
  - adaptability in configuration arrangement to a great variety of multi-discipline, dedicated discipline, or application modes.
  - good dispersion and viewing freedom for payloads up to 12 meters in length.

- The subsystem approaches recommended are based on a logical and cost-effective allocation of functions among payloads, Platform, the Power System, and ground support elements.

- Although most candidate payload definitions/requirements are currently sketchy, the great number and diversity of payloads (50-60) accommodated by the selected platform concept constitute a solid foundation for the concept.

- The T-bar/cruciform configurations inherent in the recommended Platform, with rotary joints on each leg, provide very good viewing, separation, and loading features for payloads.

- Deployable structures offer stowage compaction advantages for long extension arms. Structural dynamics modeling and development testing is required.

- Stabilization of 1.5 arc seconds can probably be achieved with an instrument pointing system for payloads with Platform structure selected.

- The impacts of transition of Spacelab sortie payloads to Platform flight can be minimal.

- Shuttle RMS support of Platform deployment and loading requires a special berthing arm for the extended span reaches involved or RMS relocation.

- The reference Power System used in the study fulfills most Platform/payload requirements but numerous minor changes are suggested.

- The study raised many design and operational issues which require more detailed analysis to better address (1) the emerging interface definition needs of the recently initiated Phase B Power System study, and (2) the accommodation needs of representative mission scenarios, recently outlined in the companion TRW study.

10.2 PAYLOAD REQUIREMENTS AND ACCOMMODATIONS

- Early automation of the voluminous, 70+ payload requirements documentation saved considerable man-hours in the study.

- Seven or eight extremely large payloads were not used in sizing the Platform, but were instead relegated to the Advanced Platform (80 X 160 meter cruciform)

studied under a parallel effort for the Langley Large Space Systems Technology Office through MSFC.

- Configuration sizing requirements are driven by prospective payload dimensions and extensive operational movement. Cross arm separation from the PS solar array was established to avoid possible collision risk. Cross arm docking port separations were established to avoid collision between adjacent payloads during scanning (60° sweep cone instrument pointing system assumed).

- Five distinct orientations have been recommended for various SASP configurations for viewing requirements that call for one, two, and three viewing directions. Of the cases examined, approximately 25 percent of the cases call for an X-POP, Y-PSL orientation. Orientation flexibility is a basic requirement to meet the various viewing needs.

- Payload inclination ranges show a descending order of preference for 28.5°, 70°, 90°, and 56°. Orbit altitude preferences peak strongly at 400 km.

- Scheduled payload stay-time on orbit will strongly impact platform size, loadings, and platform numbers.

- Conservative loading of platforms appears prudent from many integration and operation reasons.

10.3 POWER SYSTEM INTERFACES

- The PS should add ±Y docking ports complete with 25 kW electrical supply (30 and 120 VDC) and heat rejection capability.

- Added study is needed to assess the value of the +Z docking port since a gimballed payload in a +Z viewing position must be constrained to prevent payload/radiator collision.

- The PS should increase its KSA link capability to 300 Mbps and increase its data storage capability.

- The PS should provide two $0^\circ \pm 90^\circ$ gimbals that rotate about both the Orbiter and PS docking port centerlines. These offset gimbals are needed to provide RMS access to the Propulsion Module and to the +Y docking port.

10.4 CONTAMINATION

- Contamination risk for sensitive payloads will reach maximum potential starting with onset of Orbiter Rendezvous and continuing until after Orbiter departure. At a minimum this will include all payload servicing or maintenance, payload changeout, resupply operations, solar array retraction and deployment, RMS operations, Orbiter leakage, and Flash Evaporator operation. The levels of contamination are expected to exceed nominal payload limits during this time period and it seems prudent to recommend protection covers for all sensitive payloads.

- Preliminary outgassing calculations were made for what is believed to be a representative SEPS solar array (exclusion of the deployment system) and the predicted Number Column Density falls about four orders of magnitude below payload limits.

- Every effort should be made to obtain representative flight data results (SEPS arrays, Spacelab experiments, Orbiter deployment and recapture of satellites, etc.), using the NASA/MSFC developed Induced Environment Contamination Monitor (IECM) which will measure both gaseous and particulate matter.

- All results from IECM testing should be fed back into the computer modeling and materials testing to update and improve contamination predictions.

- Payload scheduling should avoid scheduling highly sensitive payloads with those predicted to have high effluent rates either due to outgassing or to particulate generation.

10.5 PLATFORM CONFIGURATION DRIVERS

PAYLOAD REQUIREMENTS

- SIMULTANEOUS MULTI-DIRECTIONAL VIEWINGS
  - DRIVES OVERALL CONFIGURATION
- R01 MEC
  - 25 kW POWER DRIVES POWER SUBSYSTEM AND THERMAL CONTROL SUBSYSTEM
  - 10^{-5} LIMIT DRIVES OPERATIONS
- PROVIDE HEAT OUT = ELECTRICAL POWER IN
  - DRIVES THERMAL CONTROL SUBSYSTEM
- LIFE SCIENCES PAYLOADS
  - 40°F DRIVES THERMAL CONTROL SYSTEM
- CRYOGENIC RESUPPLY
  - DRIVES OPERATIONS AND DESIGN
- S014 (MAGNETIC PULSE EXPERIMENT)/SPP3 (WAVE PARTICLE INTERFEROMETER)
  - 25 kW DRIVES POWER SUBSYSTEM
- R42 (EARTH RESOURCE SAR)/R48 (OCEAN SAR)
  - 120 MBPS DRIVE DATA SUBSYSTEM
- R41 (ICE/CLIMATE EXPERIMENT)
  - 25 MBPS FORWARD LINK DRIVES DATA SUBSYSTEM
- S011 (PARTICLE BEAM INJECTION) AND S013 (GRAVITY WAVE ANTENNA)
  - 400 – 250 kW PEAK POWER DRIVES POWER AND THERMAL CONTROL SUBSYSTEMS
- PAYLOAD SIZE
  - DRIVES PLATFORM SIZE
- HIGH ORBIT ALTITUDE REQUIREMENTS
  - SYSTEM PERFORMANCE

EXTERNAL SYSTEMS

ORBITER

- SINGLE RENDEZVOUS PER MISSION
  - IMPACTS PAYLOAD BERTHING CONCEPTS
- RMS REACH AND PAYLOAD MASS CONSTRAINTS
  - IMPACTS PAYLOAD BERTHING CONCEPTS
- PAYLOAD DELIVERY CAPABILITY
  - DRIVES WTR MISSION OPERATIONS
- PAYLOAD LAUNCH ENVELOPE
  - LIMITS FIXED STRUCTURE LENGTH
  - CONSTRAINS STRUCTURE CROSS-SECTION
- ORBITER EFFLUENTS
  - CURTAILS PAYLOAD OPERATIONS

TDRSS

- 50 KBPS (MULTIPLE ACCESS CHANNELS)
  - LIMITS CONTINUOUS DATA DUMP
- 300 MBPS (SINGLE ACCESS CHANNEL)
  - DRIVES DATA PROCESSING SYSTEM

REFERENCE POWER SYSTEM

- INTERFACES
  - DRIVES PS TO PLATFORM INTERFACES
- 10-16 kW HEAT REJECTION
  - DRIVES THERMAL CONTROL
- TWO-DEG POINTING ACCURACY
  - DRIVES POINTING

10.6 SUMMARY LIST OF TRADES FROM TASKS 1, 2, 3, AND 4 (See next four pages.)

Trade or Analysis	Results
1st Order configuration	
2 vs 3 vs 4 payload berthing ports	3 active payload berthing ports (1 park)
Fixed vs moveable berthing ports	4 position clocked berthing ports
Bottom vs side or end pallet mounts	Bottom mounted pallets
Standoff mini-arms vs direct-to-power system pallet mounting	Standoff mini-arms
Fixed vs scheduleable vehicle orientation	Orientation variable
2nd Order configuration	
Basic shape and compaction (many concepts evaluated)	Folding cross-arms with fixed standoff structure (T-bar)
2 vs 3 arms	Payload/program dependent
Degree of arm rotational capability	±180 degree full length arms 360 degree mini-trail arm
Payload berth separation	13.2 m
PS standoff separation	13.4 m
Fixed vs scheduleable vehicle orientation	Variable orientation
Number of primary berthing ports	5 to 9 (program dependent)
Structural elements and materials	
Fixed truss configurations	Square X rectangular box (sing. diag. truss)
Deployable truss configurations	Telefold (cable drive)
Truss material	Graphite/epoxy (alum. if covered by radiator)
Attitude control	
Concept approach	PS control (more magnetic torquers requested)
Momentum dump considerations	Options identified – orientation and payload dependent
Preliminary modal analysis	Designed in structural damping recommended to improve critical system stability
External disturbance analysis	Methods identified to reduce disturbances
Open loop AGS pointing system disturbance response	Pointing performance potentially much better than orbiter – closed loop analysis needed to assess ultimate performance
Thermal/structural response	Acceleration levels and line of sight disturbances identified – potentially not significant impact
Example payload group evaluation	CMG desaturation every 4 orbits, less with orientation skewing
Communications and data management	
Centralized versus distributed payload data processing	Distributed
Payload data storage on power system, platform or pallet	Power system for 1st order platform, supplement by platform system for 2nd order
Multiplexing on power system versus platform	Power system for 1st order platform, supplement by platform system for 2nd order
Berthing equipment	
1st order platform berthing system	Reference power system berthing unit with 1st order platform berthing adapter
2nd order platform berthing system	Reference power system orbiter berthing unit with telescoping boom
Alternate payload carrier	
Many evaluated	Ring-type carrier appears advantageous
Thermal control	
Centralized versus pallet radiator	Centralized
Loop arrangements – parallel or series	Parallel
Payload interface options	2 loops with direct fluid interface
Centralized radiator-dual loop alternates	Separate panels optimum
Centralized radiator flow options comparison	Panels in series (4 passes per panel is optimum)
Payload cryogenics	
Cryogenic resupply interface trade	Passive cryogenic cooling requires on orbit fluid transfer
"Common" platform mounted tank size	1.5M tank diameter is optimum
Tank replacement versus tank refill	Tank replacement
Tank refill analysis	Refill from supercritical source or large amounts not feasible
Replacement tank location trade	Payload or accessory pallet location optimum
Power distribution	
Platform power circuit protection/switching options trade	Remote control circuit breaker preferred
Cross-arm power distribution option trade	Radial circuits from support module distributors
Peak/pulse power loads options trade	Power system capability used up to ~~6.5~~ 20 kw at cross-arm berthing ports, payload provides above this (25 kw available at ±Y and X ports of power system and at platform trail arm berth)
Mechanisms	
2nd order platform arm design	Fixed truss with deployable extensions
Rotating joint options	Two-stage in-line utility barrels; EVA replaceable
2nd order platform tolerance	All concepts had relatively small error
2nd order expandable structure service routing concepts	Loop service lines and cables
Support module concept options	Isogrid box with elbow hinges for arms
Pallet access	
1st order (dual hub adapter or multiple dock)	Dual hub adapter
2nd order (dual hub/telescopic, multiple dock or relocated rms)	Dual hub/telescopic

Trade or Analysis and Results

10.7 STABILIZATION AND CONTROL

- The reference PS can provide basic attitude control for the SASP with some restrictions on orientations and/or orientation hold durations.

- SASP can accommodate low-g payloads with some restrictions on pointing system maneuvering, payload location, and PS operation. Orbiter thruster and crew disturbances appear unacceptable in the Sortie-combo mode.

- Most pointing payloads can be accommodated but pointing system rastering and slewing operations may be restricted to some degree when multiple pointing systems are operating simultaneously.

- Thermal induced acceleration transients are acceptable to low-g and pointing payloads when graphite/epoxy structures are used. Uncoated aluminum structures could result in unacceptable accelerations for low-g payloads. Pointing payload line-of-sight disturbances of about 0.04 arc sec are possible with uncoated aluminum.

Recommendations

- The SASP should provide capability to transfer payload sensor data to the PS attitude determination algorithm.

- The SASP structure should not result in PS/SASP vehicle system flexible modes below 0.1 Hz (except solar array modes).

- Further analysis is required in the following areas:
  - Detail orientation requirements.
  - Mounting of pointing systems on flexible structure.
  - Operation of multiple pointing system simultaneously on flexible structure.
  - "Shaped-torque" torque commands for maneuvering and pointing system slewing and rastering.

10.8 COMMUNICATIONS AND DATA MANAGEMENT

- The SASP should provide a centralized data storage capability for payload scientific data.

- The trend toward autonomous data processing within the payload equipment (dedicated experiment processors) has advantages for a SASP concept and should be encouraged.

- Spacelab payloads can be integrated with a SASP data system by installing new interface adapters (modules or cards) on the payload side of the interface. This change will be eased for payloads that use a modular interface electronics concept such as SPSME.

- The requirements and design concepts for on-board data processing support of payload pointing system have not been adequately examined and need additional study.

- The impact of the recommended SASP approach on Spacelab payloads that are highly dependent on experiment computer support should be studied in more depth.

10.9 END-TO-END DATA FLOW

- The SASP communications and data management system should be designed to minimize the usage of TDRSS timeline.

- The SASP approach has a significant advantage over free-flyers in efficient utilization of TDRSS because of its capability to assemble data from multiple payloads and dump it to TDRSS at high rates.

- The combined requirements of multiple payloads for real-time or near real-time data for interactive control will probably exceed the bit rate

capability of a single TDRSS MA channel. A possible solution is to use multiple MA channels. Further study is needed to better define the requirement and to explore alternative solutions.

10.10 THERMAL CONTROL

- Centralized radiator concept selected because of higher performance and reduced hardware requirements.
- Power System plus Platform radiator on standoff section is adequate.
- Peak loads accommodated by thermal capacitors or elevated temperatures.
- Dual loop with payloads in parallel is the selected loop configuration.

10.11 CRYOGENICS

- Payload-provided cryogenics approach was chosen based on limited available data.
- Tank replacement on payload is necessary for IPS-mounted payloads.
- Platform-provided concept evaluated later when more data becomes available.

10.12 POWER

- Distribution capability of 25 kW average/35.5 kW peak at 30 VDC and 120 VDC for payloads on mini-arms. (Peak of 35.5 kW at 120 VDC reflects potential capability of Power System versus rated capability of 27.0 kW.)
- Distribution capability of ~~6~~ 20 kW average/~~9.3~~ 24 kW peak at 30 VDC and 120 VDC for payloads on cross arms.
- Flexibility for supplying peak power while maintaining maximum isolation between payloads.

- Peak loads exceeding power distribution capability require peaking batteries at payload.

- Provision for growth to extended second-order platform with minimal scar.

10.13 PLATFORM STRUCTURAL/MECHANICAL SYSTEMS

- Structural Configuration

  Majority portions of the Platform may utilize fixed instead of the expandable truss except for the growth option of the cross arms which will be assembled further downstream in the program and should be highly compacted to minimize launch storage volume.

- 1st Order Arm Configuration

  The active and passive Orbiter and payload berthing should be interchangeable with any other parts on the Power System and Platform and payload carriers. The payload carrier should be bottom mounted. The automatic payload rotation and pointing system was selected over the manual EVA point to improve its real time viewing flexibility and eliminate the EVA activity.

  The bottom-mounted payload berthing port was selected over the end and side mount. The side concept was not selected because of its thermal distortion characteristics and platform structure supports being large and complicated. The end-mounted was not selected because it used additional launch volume and each payload would require an adapter, and it was also not compatible with the concept already selected on the Second Order SASP.

- 2nd Order SASP Configuration

  The study concluded that the 2nd order basic configuration will require the following.

- Many variations of extension structures were reviewed and the conclusion was that the telefolding truss concept is best because of its automatic deployment feature, folding and high compaction ratio. The basic second order concept is all fixed truss which had the advantages of stiffness and reduced free play.

- Extended standoff for payload rotational clearance and location to mount radiators.

- Support module to house the thermal control system, electronics, and (1) berthing port, and Orbiter berthing interface, and (1) berthing port for the trail arm. It also has the mechanism to fold the two crossarms and the three active berthing ports each for the payload and growth expandable crossarms.

- Further study on the modification to the ERNO pallets should be accomplished caused by the impact of the bottom mounting, such as coolant and wire routing and thermal distortions of this type of interface.

Berthing Ports

Many concepts of the berthing ports were studied and selected concept (developed on overstudy for JSC/LaRC) fulfilled majority of the requirements. The other concepts could not meet the under-pallet Orbiter clearance envelope, and some designs could not meet the alignment error of the RMS.

10.14 ROTATION JOINTS

The Platform requires several different configurations of the rotational joint to satisfy the pointing, viewing, and servicing functions. The following configurations are:

- 360° rotation (2nd order trail arm).
- ±90° rotation (1st order cross and trail arm and berthing adapter).
- ±180° rotation (2nd order cross arms).

The recommended 360° rotational joints subsystems are:

- Roll rings selected for power and data transfer.
- Roller type suspension and friction drive for smooth operation and module design.
- Brushless DC drive motors for long life and lightweightness.

1st Order Cross and Trail Arm Joints

The rotation required will be ±90° for all the arms. The indexing will be a three-position stop at 0 ± 90°.

2nd Order Cross Arm Joints

The rotation required will be ±180° with infinite stop positions between the 0 to ±180° stops.

Our recommendation is not to transfer fluid across the 360° joint. The fluid seal leakage and wear will limit the life of the assembly, and replacement in orbit is considered impractical.

The fluid transfer across the ±90° and ±180° can be accommodated with a swivel joint which can be easily quick uncoupled and replaced by EVA without fluid spillage. The power and data cables will be flexed across the joint without roll rings.

1st Order Platform Berthing System

An Orbiter to Power System berthing port adapter is required to supplement the reach of the RMS and clearances. The dual-hub adapter selected requires the capability to rotate ±90° on both the active and passive ports.

10.15 SHUTTLE INTERFACES

- Rendezvous
  - The acceptable rendezvous technique developed to achieve a soft dock will have a major impact on Power System, Platform, and payload design and be a major concern to the RMS.
  - The technique selected will be required to provide an acceptable "slow" approach with optimum collision avoidance and minimize contamination.
  - Subsystems on the PS and Platform may require retraction, rotation, or temporary protection during rendezvous operation.
  - Sensors and delicate experiment components may require protection and/or may require stowing provisions during rendezvous.
  - Using the RMS for attenuation at the final berthing maneuver may be beyond the capability of the RMS. The Second Order Platform, when fully loaded with scientific experiments, will surpass the weight criteria used for the RMS design. Also, the SASP will be an active, controllable satellite at time of the berthing operation which may have a serious effect on the RMS operation.
- Berthing
  - Attaching the Orbiter to the SASP in such a manner as to place payloads within reach envelope of the RMS with Orbiter limited to a single berthing operation is a major design impact on the SASP.
  - Study results indicate that berthing with the SASP can be accomplished with a common Orbiter berthing system and an adapter configured for the 1st Order Platform and an adapter configured for the 2nd Order Platform.

- Study results and experiment requirements indicate that the berthing interface must provide rotational capabilities for RMS access to (Y) axis payloads and maximize RMS access to Orbiter cargo bay.

- It has been concluded that the berthing system incorporated must place (Y) axis payloads forward of Orbiter station Xo 679.5 to enable the RMS to be properly oriented.

- <u>Platform Deployment - 1st Order</u>

  - Placing payloads on the +Y, -Y, and +X Power System ports satisfies the multi-viewing requirements imposed by the experiments.

  - Using only three active ports on the PS enables the remaining port to be exclusively for payload parking. This configuration satisfies the viewing requirements with no impact on Orbiter, Orbiter equipment, Payload Systems and does not require special Power System equipment for payload parking.

  - The mini-arms incorporated can be launched as separate items with the PS and attached on-orbit by the RMS operator. Each identical arm provides (4) direction viewing at each port.

- <u>Platform Deployment - 2nd Order</u>

  - Transition from a fully loaded 1st Order Platform to a 2nd Order Platform can be made with minimum interference with the 1st order experiment program. Transition requires the +X located payload be placed on the PS parking ports. If the parking port was active, no interference would occur.

  - The 2nd Order Platform, after berthing to PS, is automatically deployed and verified without the use of the RMS and without EVA assistance.

- After the initial deployment, a 2nd order berthing adapter is required to position the Orbiter within reach of each of the payload berthing ports.

- Cross-arm capacity can be doubled with the addition of self-deployed structural extensions, design to interface with the basic 2nd Order Platform, and provide improved experiment separation.

- Experiment requirements indicate that all viewing parameters can be accommodated with arm rotation of $\pm 180°$. This method of rotation eliminates the need of rotary fluid joints and slip rings.

- Platform Loading - 1st Order
  - RMS access to all 1st Order Platform payloads requires incorporation of berthing system that places the payloads at approximately Orbiter sta Xo 550 and provides a $\pm 90°$ rotation at the PS/Orbiter interface.

  - Addition of berthing adapter to permit loading with standard RMS, appears more flexible for Platform growth and/or reconfiguration than does other methods, such as RMS redesign.

  - Pallet installation on platform berthing mechanism will require visual assistance to the RMS operator from TV cameras, or equivalent, on the Platform.

- Platform Loading - 2nd Order
  - Physical characteristics of the 2nd Order Platform places the payload berthing positions outside the capability of the Orbiter with a single standard RMS.

  - Incorporation of a telescoping 2nd order berthing adapter places all

payload ports within range of the standard RMS by repositioning the Orbiter while still maintaining a positive structural attachment.

- RMS operator visual observance of the loading procedure is restricted and requires platform-mounted TV cameras, or equivalent, to assist in placing payloads in berthing mechanism.

- Subsystem Interaction (Umbilicals)
  - The remotely extended and retracted umbilical panel concept is considered state-of-the-art and no major problems are foreseen.
  - Study results indicate that all umbilical interfaces between the Power System, SASP, and payload carriers can be designed identical. The umbilical at the SASP/Orbiter interface may require a special configuration to permit crew egress through berthing mechanism.

10.16 FLIGHT OPERATIONS

- The preferred SASP configurations are self-deployed, automatically aligned and verified, remotely controllable, and receives payloads without EVA assistance.

- EVA can be reserved for maintenance and experiment reconfiguration.

- No Orbiter modifications are required.

- A parking position suitable for excepting a 12 m long payload is recommended for the 2nd Order Platform to enable off-loading Orbiter without special handling equipment.

- Initial timeline studies indicate experiment interchange may be a slow, time-consuming operation due to the size and mass of the SASP and the

payloads being exchanged. Times are dictated by the RMS limitations.

- Experimental payloads will be required to cease operation and perhaps return to a stowed position during exchange operations. This is to prevent damage due to external disturbances.
- All identified flight operations can be performed by the Orbiters standard equipment with the addition of special configured berthing adapters.

10.17 PAYLOAD CARRIERS

A comparison of the various payload carrier options resulted in the following conclusions.

- Experiments designed to operate free of the Orbiter need only a simple, lightweight carrier designed to protect the experiment in the launch environment. A suitable ring-type has been developed in this study.
- The wide range of payload types, sizes, and requirements indicated that a modular carrier designed compatible with all types of payloads may be the most economical for the SASP application.
- The Spacelab pallet is designed for use in the Orbiter and is configured as not to impose viewing restrictions from the cargo bay. It is designed to sustain high vending moments and thus is heavy in terms of weight to payload supported. SASP payload carriers can be less complex, lighter, and still thermally compatible with SASP.

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